

NCHRP

RESEARCH REPORT 899

Broadening Integrated Corridor Management Stakeholders

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**Broadening Integrated Corridor
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(continued on page vi)



FOREWORD

By William C. Rogers

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Transportation Research Board

NCHRP Research Report 899 addresses a broad range of operational and efficiency issues that are critical to bringing non-traditional (freight, transit, incident response, and non-motorized) stakeholders into the integrated corridor management (ICM) process. The guidance is based on documented lessons-learned from agencies that have implemented ICM, and includes institutional, technical, and organizational approaches such as: cooperative procedures and agreements, operational constraints and opportunities, potential ICM strategies, evaluation methodologies, and performance measures related to successfully incorporating freight, transit, incident response, and non-motorized transportation into ICM.

ICM is a relatively new congestion management approach that has been gaining interest for its potential to mitigate congestion with few changes to the existing transportation infrastructure. The primary objective of any ICM system is to coordinate the assets and expertise of multiple stakeholders rather than have each one respond to related issues independently. By integrating the management and operations of the corridor system, the complete corridor infrastructure may be better utilized, thus resulting in improved travel conditions in the target network.

Under NCHRP Project 03-121, Cambridge Systematics was asked to develop guidance for transportation decisionmakers to incorporate freight, transit, incident response, and non-motorized stakeholders into the ICM process. Conversely, the guidance is intended to inform the stakeholders from freight, transit, incident management, and non-motorized roadway user groups of the benefits they can expect to realize from greater integration with ICM.

The guidance provides resources to (1) equip transportation decisionmakers with a systematic approach to engaging non-traditional stakeholder groups in ICM planning; (2) give transportation decisionmakers the tools to present a strong case to management on why to involve non-traditional stakeholder groups; and (3) provide transportation decisionmakers with insights on the objectives and needs of each non-traditional stakeholder group to develop win-win scenarios to engage non-traditional stakeholder groups to come on board the ICM planning process.

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ABBREVIATIONS

3PL	Third-party logistics
AMS	Analysis, modeling, and simulation
APC	Automated passenger counter
API	Application Programming Interface
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
ATDM	Active transportation and demand management
ATMS	Advanced Traffic Management System
ATRI	American Transportation Research Institute
ATTS	Arterial Travel Time System
AVL	Automated vehicle location
AWIS	Automated Work Zone Information System
BCO	Beneficial Cargo Owners
BRT	Bus rapid transit
C2C	Center-to-center
CAD	Computer-aided dispatch
Caltrans	California Department of Transportation
CB	Citizens band
CCTV	Closed-circuit television
CHP	California Highway Patrol
CMM	Capability Maturity Mode
CMS	Changeable message sign
CO	Carbon monoxide
ConOps	Concept of Operations
C-PeMS	Corridor Performance Measurement System
CPS	Congestion pricing system
CV	Connected Vehicle
CV/AERIS	Connected Vehicle/Applications for the Environment: Real-Time Information Syntheses
DART	Dallas Area Rapid Transit
DIRECT	Dynamic Intermodal Routing Environment for Control and Telematics
DMP	Data Management Plan
DMS	Dynamic message signs
DO	Drayage operators
DOT	Department of Transportation
EMS	Emergency medical services
EPA	Environmental Protection Agency
FRATIS	Freight Advanced Traveler Information System
GTC	Genesee Transportation Council
HAR	Highway advisory radios
HAZMAT	Hazardous materials
HOT	High-occupancy toll

HOV	High-occupancy vehicle
ICM	Integrated Corridor Management
ICMS	ICM system
IMTMS	Intermodal Transportation Management System
IRI	International roughness index
ITS	Intelligent transportation systems
LACBC	Los Angeles County Bike Coalition
LCS	Lane Closure System
LRT	Light-rail transit
MARC	Mid-America Regional Council
MOPS	Measure of performance
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
MTO	Marine terminal operator
MTS	Metropolitan Transit System
NAS	National Air Space
NCTD	North County Transit District
NITTEC	Niagara International Transportation Technology Coalition
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrous oxides
NPS	Network Prediction System
NVOCC	Non-vessel operating common carrier
NWS	National Weather Service)
NYCDOT	New York City Department of Transportation
O&M	Operations and maintenance
O-D	Origin-destination
OS/OW	Oversize/overweight
PeMS	Performance Measurement System
PMP	Project Management Plan
PSR	Present serviceability rating
RAMS	Regional Arterial Management System
REMS	Regional Event Management System
RMIS	Ramp Meter Information System
RTMS	Regional Transit Management System
RTOC	Regional Traffic Operations Center
RTSS	Real-Time Simulation System
SANDAG	San Diego Association of Governments
SEMP	Systems Engineering Management Plan
SMU	Southern Methodist University
SOV	Single-occupancy vehicle
SPS	Smart Parking System
SR	State Route (page F-2)
TDM	Travel Demand Modeling
TEARS	Targeted Event Accelerated Response System
TIM	Traffic incident management
TMA	Transportation Management Association
TMC	Traffic management center

TOC	Transportation operations centers
TSMO	Transportation Systems Management and Operations
TSP	Transit Signal Priority
TTI	Texas A&M Transportation Institute
USDOT	United States Department of Transportation
V/C	Volume-to-capacity
VDS	Vehicle detection system
VMS	Variable message sign
VMT	Vehicle miles traveled
VOC	Volatile organic compound
VSL	Variable speed limits
WDOT	Washington Department of Transportation



CONTENTS

1	Chapter 1 Introduction
2	Objectives of the Guidebook
3	Value of Integrated Corridor Management
4	Value of Incorporating Non-Traditional Stakeholders
10	Integrated Corridor Management Planning Framework
12	Integrated Corridor Management Capability Maturity Model
14	Chapter 2 Identify & Diagnose Problem
14	What Is the Main Problem We Are Trying to Address? Is it Related to Improving Mobility, Reliability, Safety or Other?
15	How Do We Diagnose and Characterize the Problem?
17	Is This Problem One That is Suitable for ICM?
19	Chapter 3 Establish ICM Objectives & Scale
19	What Goals Are We Trying to Achieve in Addressing and Mitigating the Identified Problem?
19	What Measurable Objectives Should We Set in Order to Determine Whether This Project Is Successful?
20	What Are Some Tiered ICM Implementation Options if We Don't Have the Budget to Build a Full-Scale ICM System?
23	Chapter 4 Determine Potential Partners
23	Who Will Be Directly or Indirectly Affected by This ICM Project?
26	Whom Should We Reach Out to in Each Stakeholder Group?
28	Who Is the Top Priority in Terms of Groups, Agencies, or People That We Need to Engage?
29	How Do We Identify These Entities in Our Region?
31	Chapter 5 Assess Potential Partners' Needs
31	Do We Share the Same Objectives? What Are the Main Objectives of Each Stakeholder Group?
31	What Are the Major Concerns This Stakeholder Group Has in Getting Involved in ICM?
36	Chapter 6 Designate Performance Metrics & Data Sources
36	Which Performance Metrics Should We Use to Evaluate How Well Our ICM Project Meets Our Goals and Objectives?
38	Which Performance Metrics Are Important to This Stakeholder Group?
40	What Data Can Be Used to Measure Performance Metrics of Interest?

43	Chapter 7 Engage Potential Partners
43	What Are the Benefits to This Stakeholder Group for Getting Involved?
	What Are the Benefits to Transportation Agencies for Getting This Stakeholder Group Involved?
48	What Can the ICM Project Offer to This Stakeholder Group?
52	What Are the Best Channels of Communication with Our Identified Stakeholder Entities?
57	How Do We Use the Content in This Guidebook to Create a Strong Argument to Management and to This Stakeholder Group So They Can Be Effective Partners?
64	Chapter 8 Develop ICM System Concept
64	Which ICM Strategies Will Help Us Achieve Our Goals for This ICM Project?
65	Which ICM Strategies Will Help This Stakeholder Group Achieve Their Objectives?
70	How Will This Stakeholder Group Be Involved in ICM Response Plans?
74	How Can We Analyze the Expected Impacts of the Envisioned ICM System?
74	What Resources Are Available from Successful ICM Projects?
80	Chapter 9 Initiate Formal Arrangements
80	How Do We Formulate This ICM Process So That We Can Ensure That Our Response Plans Operate Smoothly in the Long Term?
81	What Types of Arrangements Are Suitable for Our ICM Project?
82	As the Demands of Our ICM System Change Over Time, How Does Our Organizational Form Need to Adapt?
86	Chapter 10 Next Steps for Integrated Corridor Management Implementation
A-1	Appendix A Characteristics of Recurrent and Non-Recurrent Congestion
B-1	Appendix B Overview of Integrated Corridor Management
C-1	Appendix C Stakeholder Interview Participants
D-1	Appendix D Performance Measure Guidance
E-1	Appendix E Analysis Methodology, Tools, and Plan
F-1	Appendix F Data Needs Assessment
G-1	Appendix G Documentation for Integrated Corridor Management Deployments
H-1	Appendix H Institutional, Organizational, and Technical Arrangements
I-1	Appendix I Alternative Integrated Corridor Management Frameworks

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.



CHAPTER 1

Introduction

One area of transportation operations that has the potential for increased efficiency lies in how transportation agencies coordinate day-to-day operations along heavily traveled corridors. Along most urban transportation corridors, each transportation agency within the corridor (e.g., local departments of transportation, bus operators, light rail operators, etc.) typically handles operations independently, with the exception of incidents or planned events. As road users experience increased levels of congestion, delay, and incidents, this operational model has become less effective in meeting the transportation needs of the people that rely on the corridor.¹

Integrated Corridor Management (ICM) is an approach to improving transportation that takes into account all elements in a corridor, such as highways, arterial roads, and transit systems. By optimizing the use of existing infrastructure assets through coordinated transportation management techniques, transportation investments can go further. Many corridors in the country have underutilized capacity (in the form of arterials, freeway travel lanes and parallel transit capacity [e.g., bus, rail, bus rapid transit, etc.]) that could benefit from ICM. The maturation of intelligent transportation systems (ITS) technologies, availability of supporting data, and emerging multi-agency institutional frameworks make ICM practical and feasible. Many freeway, arterial, and transit optimization strategies available today are already in widespread use across the United States. Most of these strategies are managed locally by individual agencies on an uncoordinated basis. Even those managed regionally are often managed in isolation (asset-by-asset) rather than in an integrated fashion across a transportation corridor.

The United States Department of Transportation (USDOT) started the ICM Initiative in 2006 to explore and develop ICM concepts and approaches. Since then, ICM has gained traction nationwide as a way to efficiently and proactively manage the movement of people and goods in major transportation corridors. To date, improving the mobility of motorists has been the main focus of many ICM projects. This approach often neglects the needs of other roadway users. This report provides guidance for transportation decisionmakers **to incorporate freight, transit, incident response, and non-motorized transportation stakeholders** – collectively referred to as non-traditional stakeholders – into the ICM planning process. The guidance is based on documented lessons learned from agencies that have implemented ICM.

¹ Federal Highway Administration, Integrated Corridor Management and Transit and Mobility on Demand, FHWA-HOP-16-036. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16036/fhwahop16036.pdf>.

Who Should Read This Report?

The intended audience for this report includes transportation decisionmakers from state, regional, and local departments of transportation, metropolitan planning organizations, transit agencies, and other agencies that may be involved in or want to embark on an ICM effort and are looking for guidance on how to incorporate freight, transit, incident response, and/or non-motorized transportation stakeholders into the ICM planning process.

"ICM projects are 70% partnerships and relationship-building, and 30% technological."
 – Nick Compin,
 Office of Strategic
 Development,
 Caltrans

Objectives of the Guidebook

The biggest challenges and hurdles for agencies considering operational transportation improvements are most often institutional, cultural, and collaborative—not technological. In order to further the success of ICM initiatives nationwide, this Guidebook focuses on strategies, constraints, and opportunities for developing the institutional capabilities and arrangements to support effective ICM, rather than on specific technological components and considerations.

This Guidebook provides the resources to:

- Equip transportation decisionmakers with a **systematic approach** to engaging non-traditional stakeholder groups in ICM planning.
- Give transportation decisionmakers the tools to present a strong case to management on **why** to involve non-traditional stakeholder groups.
- Provide transportation decisionmakers with insights on the objectives and needs of each non-traditional stakeholder group to develop **win-win scenarios** to engage non-traditional stakeholder groups to come on board the ICM planning process.

The Guidebook articulates the value of ICM, specifically the value of broadening ICM stakeholders, and the intricacies of each individual non-traditional stakeholder group (i.e., freight, transit, incident response, and non-motorized stakeholders), including key representatives, objectives, constraints, and opportunities to benefit from ICM. Appendices provide more in-depth reference materials focusing on specific aspects of ICM. The appendices are described below:

- A. **Characteristics of Recurrent and Non-Recurrent Congestion** – Discusses several common methods for evaluating the extent, severity, and/or impact of recurrent and non-recurrent congestion, along with methods for analyzing their causes.
- B. **Overview of Integrated Corridor Management** – Provides a brief overview of ICM for readers who are not familiar with the topic.
- C. **Stakeholder Interview Participants** – Lists the stakeholders who were interviewed as part of this project.
- D. **Performance Measure Guidance** – Describes common performance measures used in ICM evaluation.
- E. **Analysis Methodology, Tools, and Plan** – Outlines the steps involved in ICM analysis, modeling, and simulation (AMS) and how it is used for alternatives analysis.
- F. **Data Needs Assessment** – Details the common data needs to support ICM and how to develop a plan to gather such data.
- G. **Documentation for Integrated Corridor Management Deployments** – Provides design details of real-world ICM systems, including the I-15 and U.S. 75 Demonstration Sites, as well as the smaller scale Kansas I-35 ICM project.

- H. **Institutional, Organizational, and Technical Arrangements** – Goes into more details and examples of institutional, organizational, and technical arrangements.
- I. **Alternative Integrated Corridor Management Frameworks** – Describes potential alternative frameworks that may be useful for ICM planning and deployment, particularly when it comes to engaging a diverse set of stakeholders.

Value of Integrated Corridor Management

Although agencies tend to measure the value of ICM through travel time savings, improvements in travel time reliability, and reduction of fuel and emissions, ICM also is valuable in developing interagency relationships and communication. The value of ICM is illustrated in Exhibit 1, which contrasts two Major Freeway Incident Response Plan scenarios for a major freeway incident that occurs during the afternoon peak period, causing two lanes of traffic to be blocked for 3 hours. The first scenario describes traffic operations without ICM. The second scenario demonstrates the value that ICM can add in such situations. The functionality of ICM is summarized in Figure 1. The outer circle lists the main elements of ICM, while the inner circle lists general ICM strategies. Table 1 provides an overview of the ICM strategies included in the FHWA demonstration sites' ICM deployments so as to provide a clear picture of what may be feasible to deploy.

Regional mobility and safety challenges will not be addressed through the actions of a single agency – active coordination among organizations is critical to solving these issues. The synergies and shared goals of the corridor operators in the scenario with ICM are clear and mutually beneficial.

Exhibit 1. Comparison of two scenarios for responding to a major freeway incident.

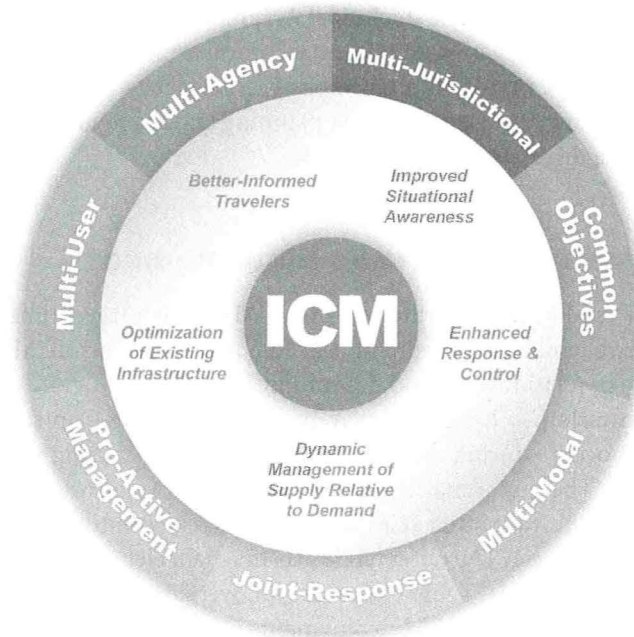
Without ICM

Traffic management center (TMC) staff receive a call reporting the incident and notify highway patrol and first responders to clear the incident. Highway patrol closest to the incident head over and set up cones to close the two left lanes affected by the incident, causing traffic to back up on the remaining lanes. Watching the action on their camera feed, TMC staff change the message on the dynamic message signs (DMSs) in the impacted area, alerting travelers to slow down, merge into the right lanes, and proceed with caution. Once the incident is cleared, highway patrol notifies TMC staff to clear the incident notification from the DMSs.

With ICM

TMC staff and highway patrol receive a call indicating the incident's location. TMC staff verify the incident on the video feed from their closed-circuit television (CCTV) cameras and review the recommended ICM response plans specified for a major freeway incident at the affected location which are generated in near-real-time by the ICM decision support system (DSS) based on the set of business rules and response postures designed for the corridor. At the same time, the incident responders use Emergency Vehicle Signal Preemption to get to the scene of the accident, shaving critical minutes off their response time. Once the incident responders close the left two lanes and assess the situation, they enter the estimated incident clearance time into the Regional Event Management System, which is automatically fed into the ICM system (ICMS). This proactive approach to traffic management by both the operators and incident responders *enhances response and control* of unexpected incidents.

Once the TMC staff and stakeholders sign off on the recommended response plan, *existing infrastructure is optimized* to disseminate pertinent traveler information to the public. The DMSs in the affected region, as well as other traveler information sources (e.g., 511) are automatically updated to broadcast incident notification, providing *improved situational awareness* to corridor users and advising travelers to take specific alternate routes or shift to transit. If the alternate route does not support freight vehicles, the traveler information sources alert trucks to stay on the freeway. The *better-informed travelers* who detour off the freeway are further aided by a new signal timing plan on the alternate route (one component of the recommended response plan) that gives more green time to the flow of the detoured traffic, while transit operators prepare for increased volumes by adding more buses or light-rail vehicles along the impacted route. This *dynamic management of supply relative to demand* reduces the negative impacts to corridor performance in the event of an incident.



Source: Federal Highway Administration

Figure 1. Functionality of Integrated Corridor Management systems.

Value of Incorporating Non-Traditional Stakeholders

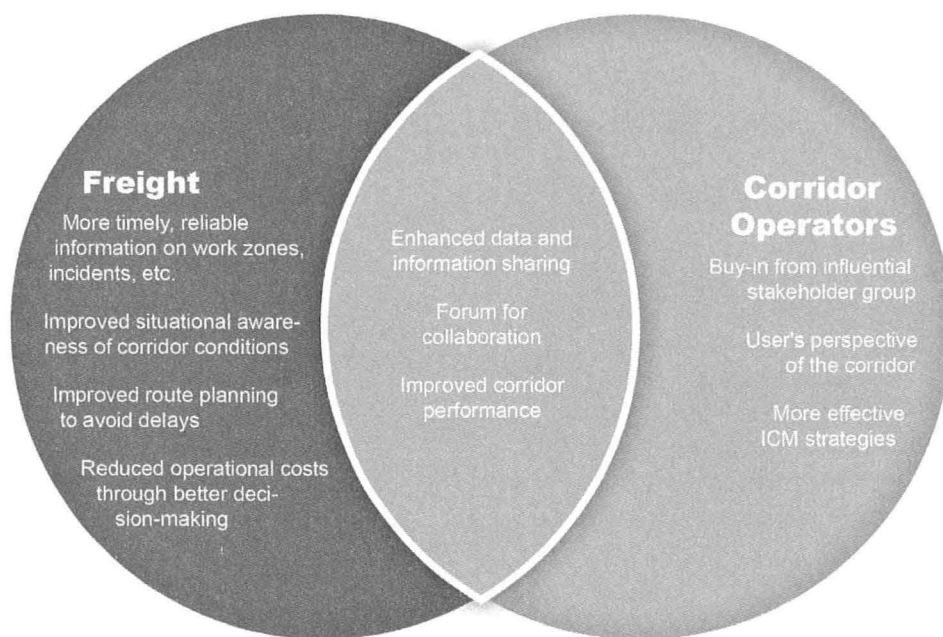
As congestion and the number of incidents steadily increase in urban areas nationwide, occasional collaboration and interaction among transportation agencies within a corridor are no longer sufficient to address the transportation needs of the traveling public. Although engaging additional groups of stakeholders is no easy task, doing so ensures that ICM strategies are designed with all roadway users in mind.

Communicating the benefits of integration may be among the most effective approaches to encourage participation in ICM projects. ICM leaders must build a compelling case to incorporate non-traditional stakeholder groups in ICM projects by understanding the benefits to corridor operators *and* to the stakeholder groups themselves. Through collaboration, both corridor

Table 1. Overview of strategies included in demonstration sites' Integrated Corridor Management deployments.

U.S. 75 ICM Strategies	I-15 ICM Strategies
<ul style="list-style-type: none"> • Providing improved multimodal traveler information (pre-trip, en-route) • Developing preapproved ICM system (ICMS) response plans • Developing a decision support system (DSS) to support ICM strategy identification and selection • Diverting traffic to key frontage roads and arterials (Greenville Ave.) with coordinated and responsive traffic signal control • Encouraging travelers to use transit during major incidents on the freeway 	<ul style="list-style-type: none"> • Active DSS • Coordinated incident management • Freeway coordinated ramp metering • Actionable traveler information • Upgrades to selected traffic signal systems (new traffic signal coordination timings, responsive traffic signal control) • Alternate route wayfinding signs

Source: USDOT Office of the Assistant Secretary for Research and Technology, Integrated Corridor Management Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas Post-Deployment Assessment Report, FHWA-JPO-16-396. Available at: <https://ntl.bts.gov/lib/60000/60400/60490/FHWA-JPO-16-396.pdf>; USDOT Office of the Assistant Secretary for Research and Technology, Integrated Corridor Management Analysis, Modeling, and Simulation for the I-15 Corridor in San Diego, California Post-Deployment Assessment Report, FHWA-JPO-16-403. Available at: <https://ntl.bts.gov/lib/61000/61100/61131/FHWA-JPO-16-403.pdf>.



Source: Federal Highway Administration, FHWA-HOP-15-018

Figure 2. Benefits of integrating freight and Integrated Corridor Management.

operators and freight stakeholders can gain insight into ICM strategies that they may not have otherwise considered. This section presents the benefits of incorporating non-traditional stakeholder groups into ICM planning into two subsections for each stakeholder group: (1) benefits for the stakeholder group themselves; and (2) benefits for the transportation agencies leading the ICM project.

Freight Stakeholders

Many urban area freight corridors are being examined as potential ICM corridors, making freight an essential ICM stakeholder. FHWA's *Integrated Corridor Management and Freight Opportunities* report² presents benefits that the freight community can expect to experience if they are integrated into ICM projects (see Figure 2).

Benefits for Freight Stakeholders

On a typical corridor, work zones or congestion management strategies are not planned, executed, or communicated in an integrated fashion. The information that is available to the public often resides on disparate channels, making it difficult to see the complete picture. In an ICM corridor, freight stakeholders can receive regular, validated information updates (e.g., travel times, incidents, work zones, road closures, suggested alternate routes, etc.) from operating agencies along the corridor. This provides truck operators and dispatchers with improved situational awareness of conditions on the corridor, which is especially critical given that the cost of congestion is felt throughout the supply chain and eventually is passed on to consumers themselves in the form of higher prices on goods and products. By becoming involved in the ICM planning process, freight stakeholders may be able to request additional

²Federal Highway Administration, *Integrated Corridor Management and Freight Opportunities*. FHWA-HOP-15-018, December 2015. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop15018/fhwahop15018.pdf>.

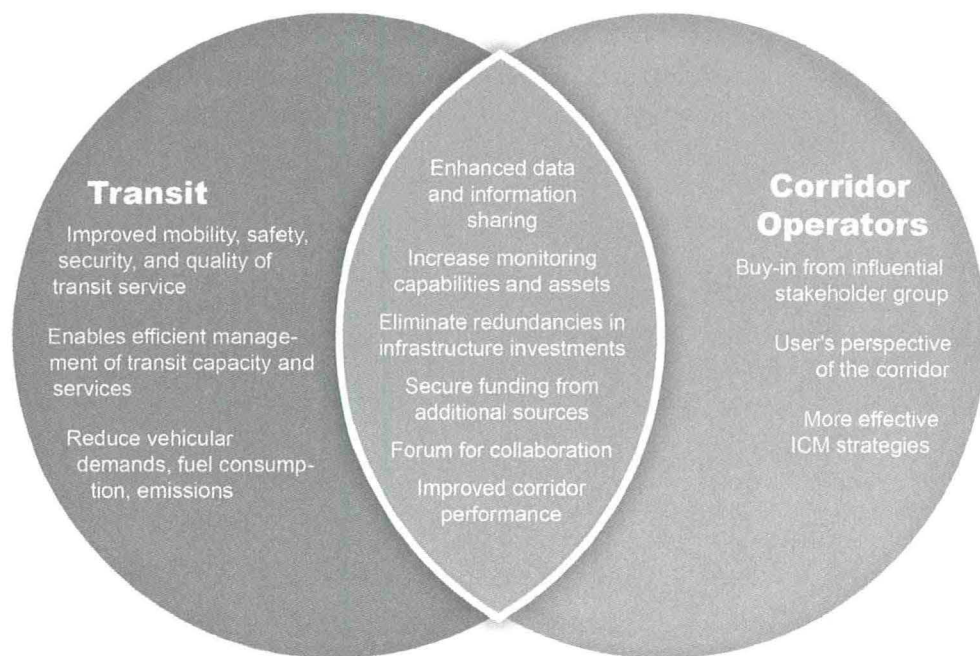


Figure 3. Benefits of integrating transit and Integrated Corridor Management.

information that they would like to receive through the ICM platform, such as information on truck-specific travel times, truck parking availability, and truck restrictions on proposed alternate routes.

With insight into accurate, current conditions along the corridor, freight operators and dispatchers can be proactive, instead of reactive, in selecting routes, timing deliveries, and managing truck driver hours of service and available equipment. Selecting alternate routes with less congestion can reduce operational costs, as a result of fuel, driver, and equipment savings.

Benefits for Transportation Agencies

Additional benefits can stem from the very act of collaborating with the freight community. Gaining buy-in from freight stakeholders can help ICM project leaders make a case for ICM in a region while providing a platform for freight stakeholders to share the unique challenges that they face from a corridor user's perspective and provide input into the design of a system that can better meet their needs. Freight community knowledge of major route decision points can also help inform the geographic scope of dynamic message signs included in ICM strategies. Untapped data that can be shared *from* the freight community (e.g., truck origins and destinations, port turn times, etc.) can help to provide a more robust picture of traffic conditions within a corridor or region.

Transit Stakeholders

FHWA's *Integrated Corridor Management, Transit, and Mobility on Demand* report³ states that the best way to gain buy-in and support from transit agencies is to articulate how ICM can help them achieve their transit-specific goals (see Figure 3).

³ Federal Highway Administration, *Integrated Corridor Management, Transit, and Mobility on Demand*. FHWA-HOP-16-036, March 2016. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16036/fhwahop16036.pdf>.

Benefits for Transit Stakeholders

ICM can improve the mobility, safety, security, quality, and efficient use of capacity for transit modes and services. ICM-transit integration can lead to enhanced data and information sharing between agencies, which is key to providing a more comprehensive picture of current network conditions. This increases the monitoring capabilities of both transit agencies and ICM corridor operators (in some cases, these roles may overlap) and can enable transit operators to better manage their resources for maximum system efficiency. For example, if a roadway incident causes motorists to switch to transit in order to avoid delays, then transit operators can make short-term adjustments in response to the incident by dispatching additional transit vehicles to accommodate the increase in demand. If long-term monitoring reveals that a certain transit route is consistently nearing maximum capacity, transit operators can make permanent changes to add additional vehicles during these recurring conditions. Transit schedules and routes can also be proactively adjusted in anticipation of planned roadway events (e.g., street closures). ICM-transit integration has the potential to increase transit ridership by enabling more efficient service, faster incident response, and improved reliability.

By disseminating comprehensive and validated data on current conditions (e.g., transit vehicle expected arrival times, travel times, delays, passenger occupancies, transfer options, etc.) in a coordinated manner, the end-users of the transportation network can benefit from better service and make more informed decisions about when and how they travel. By funding projects that improve transit travel time or accessibility, public transportation may become a more appealing travel option for roadway users, leading to increased ridership. Increased ridership leads to secondary benefits, such as increased transit service revenue, reduced vehicular demands, lower fuel consumption, and reduced emissions. In return, transit agencies may be able to increase the affordability of transit service due to increased revenue from additional riders.

Benefits for Transportation Agencies

On a planning level, coordinated planning between agencies can help identify opportunities where various improvements can be incorporated into the same design and construction and where key infrastructure (e.g., a communication network) can be implemented to serve multiple purposes and agencies. This proactive coordination can help eliminate redundancies and minimize disruptions for construction, both of which lead to significant cost savings. In addition, transit agencies that participate in a coordinated initiative like ICM may be able to make stronger arguments to secure funding for various improvements that provide direct travel time benefits for transit along an ICM corridor, such as an automated vehicle location (AVL) system for buses that feeds data into an ICM system. Transit priority signal systems on arterials, transit traveler information (e.g., transfer locations and times, accessibility, etc.), and integrated fare payment are examples of strategies that may be included in an ICM program.

Incident Response Stakeholders

Traffic incident management (TIM) can support ICM safety and mobility objectives when incidents occur along the corridor. In a reciprocal fashion, ICM is made up of tools that can help incident responders meet their objectives for responder safety, quick incident clearance, and prompt, reliable, and interoperable communications. FHWA's *Integrated Corridor Management and Traffic Incident Management: A Primer* report⁴ describes the potential for mutual benefits resulting from ICM-TIM integration (see Figure 4).

⁴ Federal Highway Administration, *Integrated Corridor Management and Traffic Incident Management: A Primer*. FHWA-HOP-16-035, January 2016. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16035/fhwahop16035.pdf>.

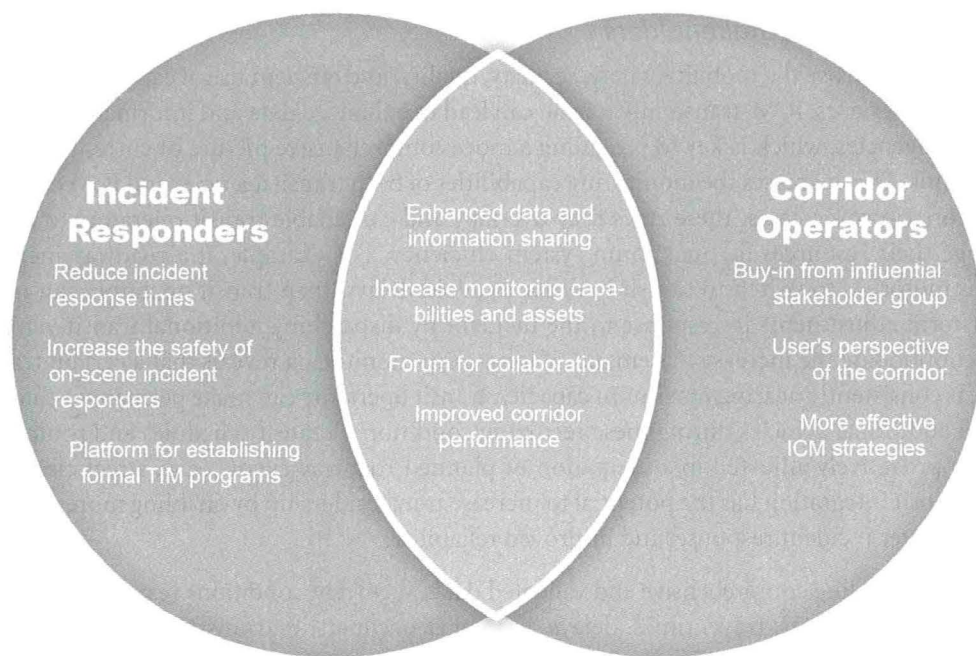


Figure 4. Benefits of integrating incident response and Integrated Corridor Management.

Benefits for Incident Response Stakeholders

Managing transportation infrastructure as an integrated system can benefit TIM programs in many ways. When incidents do occur, ICM strategies can be deployed to reroute and divert traffic away from the incident scene to clear the way for incident responder vehicles to approach the incident more quickly and safely, respond to those in need, and transport victims to care. Motorists can be encouraged to proceed more cautiously around incident responders on scene, thereby improving the safety of the responders. By diverting roadway traffic to other facilities or modes, incident queues are reduced, which helps to minimize the potential for secondary incidents, thus allowing traffic flow to be restored more quickly.

Incident responder stakeholders may also benefit from the inventory of available traffic management and transportation operations infrastructure, systems, and assets. For example, 511 systems, which are usually managed by state and regional transportation agencies, may be an effective platform for incident responders to disseminate incident alerts. Traffic management centers may also be ideal places to co-locate TIM personnel. This allows traffic operators and incident responders to share traffic monitoring video feeds and coordinate an immediate response when an incident is detected.

In areas where the TIM program may not be as well established or formalized, ICM provides a platform for collaboration among TIM partners and a proving ground for coordinated incident response. Resulting relationships among TIM stakeholders can eventually be capitalized on and used to expand and formalize the TIM program beyond the ICM corridor.

Benefits for Transportation Agencies

As with the integration of freight and transit data, the integration of TIM data helps provide an additional facet to the comprehensive situational awareness of corridor activity. Data such as anticipated incident duration, incident and roadway clearance times, occurrence of secondary incidents, and recommended alternate routes allow for more robust ICM DSS. TIM stakeholders can inform the DSS by providing valuable insights on where motorists

should be rerouted when incidents occur, or what potential corridor effects to expect from planned special events such as sporting events, concerts, major conventions, and visiting dignitaries.

By providing real-time updates about incident-related delays and expected roadway clearance times, motorists can better understand the incident impacts on travel times and make the appropriate alternate route or modal choices, which can help improve corridor performance.

Non-Motorized Roadway Users

Non-motorized roadway users are often an overlooked stakeholder group in ICM planning. However, there are opportunities for collaboration in ICM, as safety, the utmost concern of non-motorized roadway users, is also a high-priority ICM performance metric (see Figure 5).

Benefits for Non-Motorized Roadway Users

Engagement with this stakeholder group can provide insights on how they can be affected by traffic management strategies that typically prioritize motorists above all other users. For example, arterial diversion routes are usually programmed to give major arterials more green time to maximize vehicle throughput. As a result, pedestrians and bicyclists at signalized crosswalks may experience increased levels of delay, which can be exacerbated by exposure to the elements (e.g., rain, snow, and vehicle exhaust). To improve equity in these situations, ICM strategies involving signal coordination may be redesigned to consider pedestrian and bicyclist progression.

Awareness of heavily traveled pedestrian and bicyclist routes within an ICM corridor can help inform suitable diversion routes for vehicles or pedestrians/bicyclists. Non-motorized roadway users are limited in their ability to divert long distances – even half a mile may be considered a long distance to non-motorized roadway users. Also, pedestrians and bicyclists tend not to access traveler information sources pre-trip or en route as motorists do, so it may be easier to divert motorists instead.

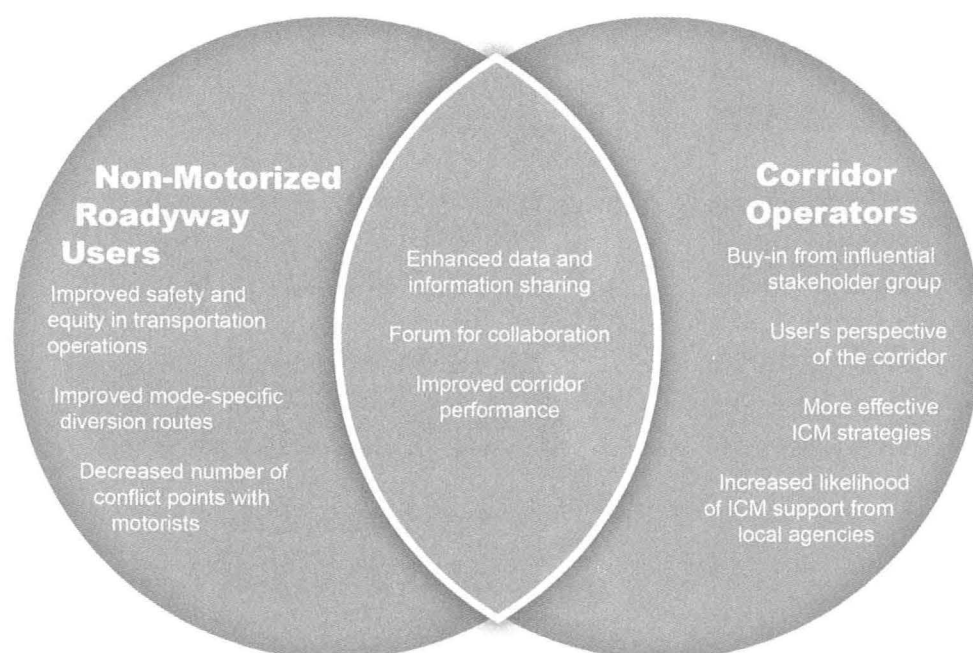


Figure 5. Benefits of integrated non-motorized roadway users and Integrated Corridor Management.

Benefits for Transportation Agencies

Several ICM projects have encountered roadblocks related to the proposed strategies that may pose additional risk to these physically vulnerable roadway users. For example, in situations of major freeway congestion, ICM strategies may temporarily route traffic onto major arterial streets – the influx of vehicle drivers who may be unfamiliar with the alternate route can cause additional safety concerns at conflict points with pedestrians and bicyclists, who may be uninformed of the sudden increase in vehicular traffic. All jurisdictions within an ICM corridor must be on board in order for an ICM project to be successful. Integrating the needs and concerns of non-motorized roadway users into ICM planning is one way to gain support from local agencies for ICM.

Increasing the convenience of non-motorized roadway usage can help reduce demand for driving. Identifying accessibility and connectivity pain points of bicyclists, pedestrians, and people with disabilities helps to develop a sustainable corridor and may also help increase transit ridership.

Integrated Corridor Management Planning Framework

This framework (see Exhibit 2) covers the main elements of the ICM planning process. It was developed to help transportation agency decisionmakers engage freight, transit, incident response, and non-motorized stakeholders in an ICM project in a way that is beneficial to all parties. Chapters 2 through 9 work through this approach, providing guidance tailored to each non-traditional stakeholder group to tackle the list of critical ICM planning questions. ICM planning questions (grouped by task) are presented in Exhibit 3. Based on agency preference, the framework tasks can be done in any order, but no tasks should be skipped.

Exhibit 2. Integrated Corridor Management planning framework.



Based on agency preference, the framework tasks can be done in any order, but no tasks should be skipped.

Exhibit 3. Integrated Corridor Management planning questions.

1. Identify & Diagnose Problem
 - What is the main problem we are trying to address? Is it related to improving mobility, reliability, safety or other?
 - How do we diagnose and characterize the problem?
 - Is this problem one that is suitable for ICM?
2. Establish ICM Objectives & Scale
 - What goals are we trying to achieve in addressing and mitigating the identified problem?
 - What measurable objectives should we set in order to determine whether this project is successful?
 - What are some tiered ICM implementation options if we don't have the budget to build a full-scale ICM system?
3. Determine Potential Partners
 - Who will be directly or indirectly affected by this ICM project?
 - Who should we reach out to in each stakeholder group?
 - Who are the top priority in terms of groups, agencies, or people that we need to engage?
 - How do we identify these entities in our region?
4. Assess Potential Partners' Needs
 - Do we share the same objectives? What are the main objectives of each stakeholder group?
 - What are the major concerns this stakeholder group has in getting involved in ICM?
5. Designate Performance Metrics & Data Sources
 - Which performance metrics should we use to evaluate how well our ICM project meets our goals and objectives?
 - Which performance metrics are important to this stakeholder group?
 - What data can be used to measure performance metrics of interest?
6. Engage Potential Partners
 - What are the benefits to this stakeholder group for getting involved? What are the benefits to transportation agencies for getting this stakeholder group involved?
 - What can the ICM project offer to this stakeholder group?
 - What are the best channels of communication with our identified stakeholder entities?
 - How do we use the content in this Guidebook to create a strong argument to management and to this stakeholder group so they can be effective partners?
7. Develop ICM System Concept
 - Which ICM strategies will help us achieve our goals for this ICM project?
 - Which ICM strategies will help this stakeholder group achieve their objectives?
 - How will this stakeholder group be involved in ICM response plans?
 - How can we analyze the expected impacts of the envisioned ICM system?
 - What resources are available from successful ICM projects?
8. Initiate Formal Arrangements
 - How do we formalize this ICM process so that we can ensure that our response plans operate smoothly in the long term?
 - What types of arrangements are suitable for our ICM project?
 - As the demands of our ICM system change over time, how does our organizational form need to adapt?

Based on agency preference, the framework tasks can be done in any order, but no tasks should be skipped.

Integrated Corridor Management Capability Maturity Model

The Capability Maturity Model (see Table 2) is a tool used nationwide to evaluate the maturity of ICM programs and is useful for self-assessment in the ICM Planning Framework. This table provides information related to the three key areas that are critical in ICM projects:

- **Operational Integration** – operating agencies within the corridor need a cooperative operational mindset, as well as interagency data and information sharing.
- **Technical Integration** – ITS infrastructure and technology are needed for monitoring, analytics, decision support systems, and information dissemination.
- **Institutional Integration** – institutional partnerships (e.g., agreements/memorandums of understanding, defined roles and responsibilities, etc.) are needed among the operating agencies within the ICM corridor.

Using the table, agencies can identify where their ICM project stands now and where they *want* to be. The levels between the current level of maturity and the end goal provide incremental steps toward achieving the desired maturity.

Table 2. Integrated corridor management capability maturity model.

		Level 1 Silo	Level 2 Centralized	Level 3 Partially Integrated	Level 4 Multimodal Integrated	Level 5 Multimodal Optimized
Institutional Integration	Inter-Agency Cooperation	Agencies do not coordinate their operations	Some agencies share data but operate their networks independently	Agencies share data, and some cooperative responses are done	Agencies share data and implement multimodal incident response plans	Operations are centralized for the corridor, with personnel operating the corridor cooperatively
	Funding	Single agency	MPO tracks funding	Coordinated funding through MPO	Cooperatively fund deployment projects	Cooperatively fund deployment and operations and maintenance projects
Technical Integration	Traveler Information	Static information on corridor travel modes	Static trip planning with limited real-time alerts	Multimodal trip planning and account-based alerts	Location-based, on-journey multimodal information	Location-based, multi-modal proactive routing
	Data Fusion	Limited or manual	Near real-time data for multiple modes	Integrated multi-modal data (one-way)	Integrated multimodal data (two-way)	Multi-source multimodal data integrated and fused for operations
Operational Integration	Performance Measures	Some ad hoc performance measure based on historical data	Periodic performance measures based on historical data	High-level performance measures using real-time data	Detailed performance measures in real time for one or more modes	Multimodal performance measures in real time
	Decision Support System	Manual coordination of response	Pre-agreed incident response plans	Tool selection of pre-agreed plans	Model-based selection of pre-agreed plans	Model-based creation of incident response plans

Source: National Cooperative Highway Research Program Project 20-68A, Scan 12-02.



CHAPTER 2

Identify & Diagnose Problem

In this initial stage, transportation decisionmakers need to first identify the transportation problem that the corridor is experiencing and diagnose the underlying causes of the problem.

What Is the Main Problem We Are Trying to Address? Is it Related to Improving Mobility, Reliability, Safety or Other?

A busy modern transportation system is inherently a dynamic entity. It never exists in pure equilibrium and is in a state of perpetual change at multiple temporal wavelengths: minute-to-minute, hour-to-hour, peak-to-non-peak, day-to-day, seasonally, and year-to-year. A time-dynamic view of the network informs a fundamental element of transportation systems management, namely, that system management is essentially a task of managing change. *As a result, it is crucial for ICM stakeholders to define operational conditions rigorously using observed data to help create a consensus view on patterns of corridor congestion.*

The transportation system is a collection of facilities, modes, fleets, infrastructure, and trip-making users that interact with each other. Under successful ICM, system performance is striving to be optimized and become better than non-integrated and not managed conditions. When defining the system it can be useful to examine boundaries of the following types:

- **Geographic** – Any transportation system is always influenced by its neighbors. There is no such thing as treating a subset of the transportation system as an independent element.
- **Temporal** – Under specific conditions or at times associated with particular events, many stakeholders may be trying to improve the performance of the transportation system.
- **Jurisdictional** – Even within a geographic boundary, many organizations may play a critical role in influencing the transportation system.
- **Functional** – The system can be defined by where and when managers have functional control as well as by the limitations of these controls. Functional boundaries can also be identified considering how data flow to and from entities associated with a transportation system. In some cases, data-related boundaries may limit the capability of the system manager to understand the state of the system or neighboring systems.
- **Modal** – A transportation system may contain interacting subsystems associated with different transportation modes (e.g., transit, freight, high-occupancy vehicle [HOV] lanes, pedestrian networks, and bike lanes). A systems definition must recognize the interactions among these transportation modes.

With the advent of more continuous data available, the ability to characterize dynamic corridor performance has improved. These conditions can be within a day (e.g., the rise and fall of congestion in a peak period) or over many days (e.g., the variation in travel times between a

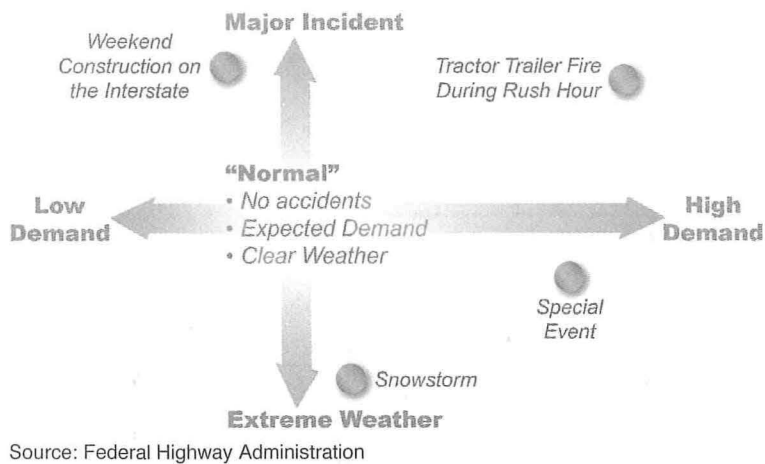


Figure 6. Various operational conditions.

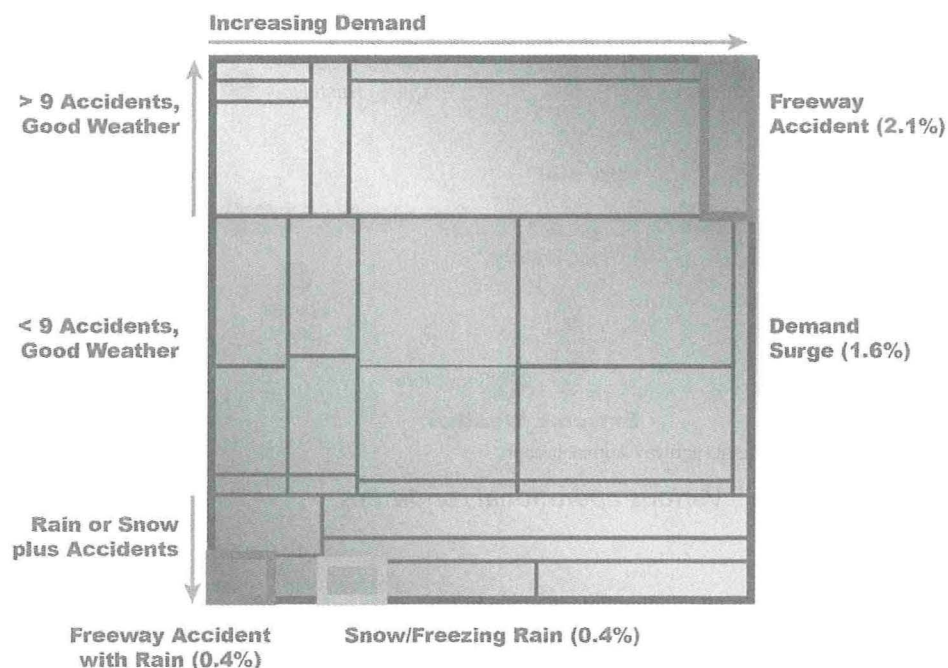
specific origin and destination departing at a specific time each day over a full year). Likewise, there is a fundamental need to develop more effective *condition-specific* corridor management responses integrating, among others, transit, freight, incident management stakeholders, and non-motorized roadway users. For ICM to be successful, vague notions of recurrent and non-recurrent congestion (convenient in a relatively data-scarce environment) are giving way to a more informed, data-driven approach that systematically classifies a wide range of operational conditions based on underlying causes (e.g., weather, incident, and demand patterns) as well as profiles of system performance (e.g., travel time, bottleneck throughput, and delay patterns).

Current ICM best practices use a data-driven method to identify multiple distinct operational conditions to better characterize transportation system dynamics. This set of operational conditions is a more effective and useful basis for comparing potential ICM response plans and is a foundational element of any effort to improve corridor performance. Figure 6 illustrates that, in order to support the development and evaluation of complex, condition-dependent ICM response plans, a systematic analysis of data to identify a practical set of representative operational conditions is required.

The characterization of a broad, accurate set of operational conditions includes special attention to outlier “bad days.” These conditions feature the highest travel times and are the conditions that make routine travel in the corridor unreliable. These conditions are particularly important to **freight** stakeholders who value on-time performance within the strictures of lean supply chain management, to **transit** stakeholders who value traveler connection protection and ridership confidence that the system will not strand them in the network, to **non-motorized** stakeholders who may be concerned about traffic diversion onto local streets, and **incident response** stakeholders who must effectively triage resources on the worst days with multiple interacting incidents.

How Do We Diagnose and Characterize the Problem?

An operational conditions analysis ingests several months of contemporaneous, time-dynamic travel time, bottleneck throughput, weather, incident, and travel demand data to create mutually exclusive and exhaustive sets of similar conditions – and their frequency of occurrence. For example, an analysis of a corridor identified 30 distinct operational conditions, depicted in Figure 7. The figure organizes the 30 conditions spatially based on increasing travel demand (along the x-axis) and disruptions to roadway supply (along the y-axis). Each condition is a



Source: Federal Highway Administration

Figure 7. Visualizing operational conditions in the Seattle I-5 Corridor.

collection of 4 or more actual days, and the total size of the box representing the condition reflects its frequency of occurrence.

ICM focuses on various multimodal travel scenarios under varying operational conditions, in particular both recurrent and non-recurrent traffic congestion. A corridor's non-recurrent congestion scenarios entail combinations of demand increases and capacity decreases. The overall premise is that key ICM impacts may be lost if only "normal" travel conditions are considered. The ICM scenarios take into account both average and high-travel demand within the corridor, with and without incidents. The relative frequency of non-recurrent operational conditions (i.e., incidents or other significant non-recurrent operational conditions that affect corridor performance such as work zones, special events, and weather) is also important to estimate (based on archived traffic conditions) in this process. Although ICM is designed to address both recurrent and non-recurrent events, the post-deployment evaluation of the two demonstration sites (Dallas and San Diego) focused solely on incident- or congestion-related events. The potential ICM deployment-related alternatives were identified using cluster analysis that grouped incidents or congestion events that occurred under operational conditions (e.g., time of day, direction of traffic, length of time until the incident was cleared, etc.) which were more similar to each other than to those in other groups (clusters). These clusters were then prioritized based on total delay impact.

Data and tools can be brought together to provide increasingly robust and quantitative measures of system performance. Some useful measures of system products over some period (e.g., a peak period, or a day, or a month) may include reliably completed trips and total value of goods delivered. These may be hard to measure directly. However, using time-variant travel time data and supporting estimates of ridership and volume data, travel reliability analysis can be conducted that is a key first step in the measurement of system product. Reliability data are a key element in characterizing trip-making given that, if a trip takes much longer than expected, the disbenefits associated with disrupting travel plans outweigh the benefits. This is particularly true for goods movement within a supply chain, but the same basic principles

hold for person-trips. For example, if a trip home from work takes so much longer than expected that changes to childcare arrangements are required, this often has direct and measurable financial consequences. The purpose of building system profiles is to characterize system performance (i.e., the system is getting better or worse) and to identify what items are missing in the profile so the profile can be improved in the long term.

Appendix A, Characteristics of Recurrent and Non-Recurrent Congestion, provides a review of different methods for visualizing and communicating the severity, extent (temporal or spatial), nature, and/or characteristics of congestion, such as through color-coded network diagrams, GIS maps, speed contour plots, travel time reliability charts, vehicle trajectory plots (i.e., time-space vehicle plots), cumulative count curves, and other methods. FHWA's *Scoping and Conducting Data-Driven 21st Century Transportation System Analyses* is another key document related to the systematic identification of operational conditions. It is a guide on the systematic integration of data and analytic resources into transportation systems management.

Is This Problem One That is Suitable for ICM?

FHWA advises transportation agencies looking to pursue ICM to go through these four steps to increase their ICM “readiness”:

1. Recognize existing infrastructure and systems for each modal network and identify whether these can be effectively integrated into ICM.
2. Distinguish whether or not existing transportation systems are being fully optimized.
3. Know whether the corridor contains alternative routes and modes for travelers.
4. Verify that relevant agencies are in support of corridor operations.

FHWA's *10 Attributes of a Successful ICM Site* fact sheet⁵ describes the importance of each attribute for effective implementation. For those not familiar with the concept of ICM, **Appendix B, Overview of Integrated Corridor Management**, covers ICM fundamentals and examples of ICM strategies.

⁵ https://www.its.dot.gov/factsheets/pdf/ICM_10Attributes.pdf.

10 Attributes of a Successful ICM Site

10 **Significant Congestion and Unreliable Travel Times**

The most critical—and obvious—attributes of a successful ICM site are noticeably high congestion and unreliable travel times. The impact of ICM is more noticeable in areas with significant congestion and delay, as improved traffic flow in these areas can be more attributable to ICM strategy implementation than in areas that experience inconsistent congestion.

9 **Infrastructural Availabilities**

ICM sites must also have the appropriate infrastructure in place to support ICM, such as parallel arterials and additional transit options. For ICM to work properly, there must be alternative means of transit to which people can shift based on the information and traffic data the system provides.

8 **Multimodal Capabilities**

ICM corridors must also have the ability to connect in a multimodal fashion. This means that the different transit organizations and agencies must be able to communicate with one another, such as bus transit, rail transit, high-occupancy-vehicle (HOV) lane management, etc. Full implementation is nearly impossible without open communication—both technologically and organizationally—between the different modes of transportation.

7 **Centralized Data Hub**

A localized transportation management center is critical for housing all communication and traffic data in one centralized location. This makes it easier to organize and analyze the different traffic data and information in a consolidated manner.

6 **Successful Procurement Practices**

The most successful ICM sites are able to identify the processes and practices that work, and the personnel needed to perform the job correctly and proficiently. For example, integrating traffic systems together requires a different set of skills and expertise than typical traffic engineering. Intelligent transportation systems (ITS) experts may need to be involved in the integration process to ensure it is completed effectively, and knowing this information in advance eliminates wasted time spent on troubleshooting. Efficient ICM sites are fully aware of expertise requirements and act accordingly during the procurement and integration processes.

5 **Readily Available Alternative Transit Options**

Alternative transit options are a necessity for successful ICM sites. These options could include bus rapid transit, HOV lanes, alternative commuter options, commuter rail, heavy rail (e.g., subway), and light rail. Effective ICM sites already have these options in place before ICM is implemented, and therefore can more easily integrate the options together.

4 **Optimization of Existing Transportation Systems**

Successful ICM sites are able to determine whether the currently existing transportation systems are being fully optimized to ensure that there are no additional underlying problems with traffic networks. For example, a site must verify that roads cannot be widened any more due to surrounding infrastructure or physical location, or validate that all additional alternative routes are being utilized in a manner that cannot otherwise be improved upon without ICM.

3 **Public Engagement**

Keeping stakeholders and the public engaged provides the public with better understanding of expected changes and better enables them to make more informed travel choices. A dedicated public-facing website that houses all of the corridor information and serves as a one-stop shop for project information can keep the public knowledgeable of recent ICM developments. It also provides the media access to all images and videos and reminds the public that the system is still in place—even after all physical changes and construction have been installed and forgotten.

2 **Open-mindedness for Change**

Change is not always easy. While some people are more susceptible to change, others may see it as a threat to the familiar routine and be less receptive. Successful ICM sites are able to encourage an open mind and acceptance to changing solutions for congestion and traffic. Encouraging the public to support the changes for the betterment of congestion and travel times is an extremely important—and sometimes difficult—task.

1 **Institutional Support**

One of the most critical pieces of successfully implementing ICM is interagency and institutional support. Without the coordination of transportation agencies and organizations, multimodal communication and coordination is extremely difficult. Deployment of the required ICM technologies can be severely delayed or even immobilized without the support of local and regional transit agencies and the ability to send information across jurisdictions. Strong leadership is also important. ICM implementation not only requires the coordination and support of external agencies and organizations, it also relies heavily on the ability to coordinate and make decisions from an internal perspective. Like most systems, ICM implementation can only fully succeed when all parties involved work together, and a strong sense of leadership is necessary to keep all of those aspects organized and the end goal on track.



CHAPTER 3

Establish ICM Objectives & Scale

Once transportation decisionmakers have determined that the transportation problem is indeed one that is suitable for ICM, they need to set measurable ICM goals and objectives.

What Goals Are We Trying to Achieve in Addressing and Mitigating the Identified Problem?

The vision of ICM is to achieve significant improvements in the efficient movement of people and goods on transportation networks through aggressive, proactive integration of existing infrastructure along major corridors. By applying an ICM approach, transportation professionals manage the corridor as a multimodal system and make operational decisions for the benefit of the corridor as a whole.⁶

The broadness, versatility, and complexity of ICM is what makes this approach an effective solution for a wide range of situations. At a basic level, the goals of ICM projects generally involve:

- Improving travel time
- Increasing corridor throughput
- Improving travel time reliability
- Improving incident management
- Enabling intermodal travel decisions
- Increasing safety for all travelers

Goals to reduce negative impacts on transportation network performance can include decreasing delay (freeway mainline, ramps, arterials), vehicle hours traveled, peak period duration, emissions, fuel consumption, speed variability, and primary and secondary incidents. Goals to maximize benefits for transportation agencies and the traveling public can include increasing capacity, speeds, transit ridership, and transit on-time performance.

What Measurable Objectives Should We Set in Order to Determine Whether This Project Is Successful?

Performance measures for ICM will typically focus on the following key areas described below. However, customized measures may be selected based on unique impacts of individual mitigation strategies. The key performance areas are as follows:

- **Mobility** – Mobility describes how well people and freight move in the study area. Three primary types of measures are used to quantify mobility, including travel time, delay, and

⁶<https://ops.fhwa.dot.gov/publications/fhwahop16035/index.htm#intro1>.

throughput. Travel time and delay are fairly straightforward to calculate. Throughput is calculated by comparing travel times under the incident scenarios to those under no incident – by comparing the percentage of trips under the same threshold travel time in both the pre- and post-mitigation scenarios, the relative influence of the strategies on reducing extreme travel times can be estimated.

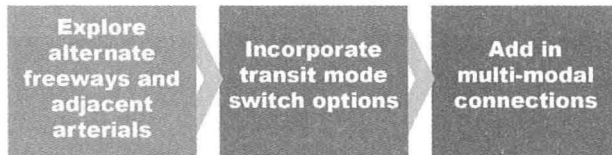
- **Reliability and Variability of Travel Time** – Reliability and variability capture the relative predictability of the public's travel time. Unlike mobility, which measures how many people are moving at what rate, the reliability/variability measures focus on how mobility varies from day to day. Travel time reliability/variability typically is reported in terms of changes in the Planning Index and changes in the standard deviation of travel time.
- **Transportation Safety** – Transportation safety is another performance area that may be of interest to transportation analysis. Safety typically is measured in terms of accidents or crashes in the study area, including fatalities, injuries, and property-damage-only accidents. Available safety analysis and prediction methods are not sensitive to transportation improvement strategies. At best, available safety analysis methods rely on crude measures such as volume-to-capacity ratio (V/C) or rely on empirical comparison methods such as identifying safety benefits resulting from the implementation of a certain type of mitigation strategy and then applying the same expected improvement rate to a future implementation of the same or similar strategy. Clearly, this is an area deserving new research.
- **Emissions and Fuel Consumption** – Emissions and fuel consumption rates are used to produce estimates based on variables such as facility type, vehicle mix, and travel speed.
- **Benefit-Cost** – Benefits should be estimated for the improvements by monetizing the incremental change in performance measures associated with the ICM strategies and scenarios analyzed. The incremental change in the performance measure should reflect the weighted sum of changes for all analysis scenarios. To estimate the benefits in annual dollar values, the annual incremental change in the various performance measures should be multiplied with an estimate of the monetary value of benefits (e.g., the value of an hour of travel time saved). Monetary values of benefits (e.g., value of time, value of accident reduction) should be consistent with those values typically applied in the region. For those performance measures with no established local value, national benefit valuations may be applied. Planning-level cost estimates include lifecycle costs, including capital, operating, and maintenance costs. Costs are typically expressed in terms of the net present value of various components. Annualized costs represent the average annual expenditure that is expected in order to deploy, operate, and maintain the transportation improvement and replace equipment items as they reach the end of their useful life.

What Are Some Tiered ICM Implementation Options if We Don't Have the Budget to Build a Full-Scale ICM System?

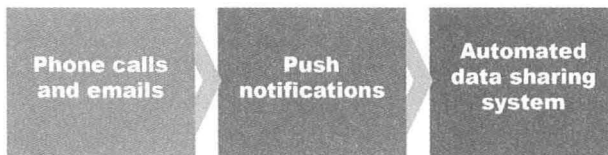
Smaller scale agencies may not have the resources or capability maturity to implement full-scale ICM projects. NCHRP's *Advances in Strategies for Implementing Integrated Corridor Management* report⁷ lists the following basic building blocks of ICM. If it is not feasible to achieve full automation right away, consider a tiered implementation approach that supports incremental growth. Possible approaches follow each bullet point.

⁷National Cooperative Highway Research Program, *Advances in Strategies for Implementing Integrated Corridor Management (ICM)*, NCHRP Project 20-68A, Scan 12-02. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_12-02.pdf.

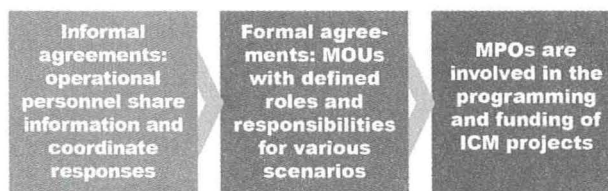
- **Available Capacity** – There must be available capacity within the transportation to manage a corridor through a multi-agency or intermodal ICM approach. If a freeway is congested, there must be capacity on an alternate freeway, the adjacent arterial network, or transit servicing the corridor for ICM to be considered.



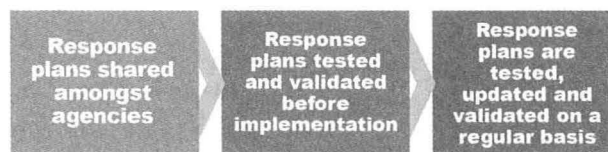
- **Exchange of Data** – There must be an exchange of data between agencies responding to an event with the managed corridor. This could be as simple as telephone calls discussing and agreeing to a response; this would be the minimum. For data exchange to be effective, the scan team recommends an automated data sharing system. Because these systems may vary among agencies responding to events, a standards-based system (e.g., center-to-center communication, National Transportation Communications for ITS Protocol, Traffic Management Data Dictionary, Message Sets for External Traffic Management Center to Traffic Management Center Communication, or transit communications interface profiles) should be used for more seamless integration.



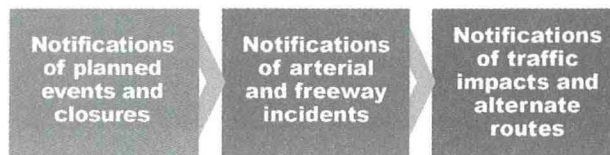
- **Institutional Cooperation** – There must be open communication and cooperation among agencies to operate the assets within the corridor. This can be done informally (i.e., operational personnel sharing information and coordinating responses among agencies) or more formally (i.e., through intergovernmental agreements or memorandums of understanding [MOUs] that define roles and responsibilities). Some areas have been successful using high-level ITS cooperative MOUs, while others have developed ICM-specific MOUs.



- **Coordinated Response** – For ICM to work properly, all agencies involved with the corridor's operations must coordinate their response to events. An agency that does not coordinate its response could negatively affect the corridor. Once the ICM program is in place and operational, it is time to test, update, and validate the response plans used by the corridor.



- **Traveler Information** – Providing timely notifications to the public about traffic conditions allows travelers to plan accordingly. A system that supports automated notifications (e.g., congestion, incidents, and strategies for minimizing delay) among operating agencies as well as the traveling public allows for more proactive traffic management and emergency routing during recurrent and non-recurrent congestion.



Determine Potential Partners

The objectives and scale of the ICM project will help transportation decisionmakers determine who will be directly or indirectly affected and which stakeholder entities could make good partners. The difference between ICM partners and stakeholders is that ICM partners would be required to support an ICM project through planning, deployment, and operations/maintenance. ICM partners may be expected to provide funding, data sharing, or operational support, while ICM stakeholders may contribute to an ICM project through user input and feedback.

Who Will Be Directly or Indirectly Affected by This ICM Project?

As a corridor is being considered for ICM, it is important that *all* agencies affecting the operations and maintenance of the network are invited and participate in the planning of ICM. It is recommended to cast a wide net early in the process, so as not to exclude possible stakeholders early on. The roles and level of involvement may differ, but in order to be most effective, the ICM team should consider all transportation resources. Below are potential stakeholders to consider as partners, broken down by non-traditional stakeholder group.

Freight Stakeholders

Freight is moved by rail, water, pipeline, truck, and air. Some common freight stakeholder entities include, but are not limited to, the following:

- **DOT freight advisory committees** – Made up of members of the freight community to advise transportation agencies on freight issues, priorities, projects, and funding needs for freight improvements. Used to ensure that private-sector freight transportation needs are addressed in the public-sector transportation planning, programming, investments, and implementation processes.
- **Freight/trade associations and user groups** – Made up of and funded by businesses that operate in a specific freight industry. An industry trade association may attempt to influence public policy in a direction favorable to the group's members through advertising, education, political donations, lobbying, and publishing. Trucking industry sectors encompass manufacturers (e.g., truck, engine, and trailer) and motor carriers (e.g., truckload carriers, less than truckload, third-party logistics providers, national parcel carriers, regional parcel carriers, moving companies, etc.).
- **Port authorities** – Port authorities are responsible for operating and setting policies for gateways for international commerce (e.g., airports, seaports, and railroads).

- **Marine terminal operators (MTOs)** – MTOs offer wharfage, dock, warehouse, or other marine terminal facilities to serve ocean carriers, providing the link for goods between ocean carriers and motor carriers.
- **Non-vessel operating common carrier (NVOCC)** – NVOCCs provide intermediary logistics planning and coordination between marine terminals and drayage trucks. An NVOCC is a cargo consolidator who does not own any vessel, but acts as a carrier legally by accepting required responsibilities of a carrier who issues their own bill of lading. Also, an NVOCC acts as “carrier to shipper” and “shipper to carrier.” An NVOCC can own and operate their own or leased containers. An NVOCC acts as a virtual carrier and accepts all liabilities of a carrier legally, in certain areas of operation.
- **Beneficial Cargo Owners (BCOs)** – BCOs are the importers and exporters of record who physically take possession of cargo at destinations and include distribution centers, warehouses, and other intermediate locations. BCOs determine when and where containers are moved, how long containers are stored, and who receives and moves containers. Depending on the size of the BCO, a BCO may either route imports to one main terminal or distribute them among several terminals. BCOs have several options to procure transportation services. They can procure directly themselves from an ocean carrier, they can contract or supply their own services, or they can work through a third-party logistics (3PL) entity.
- **Distribution centers** – Distribution centers (also known as warehouses, fulfillment centers, cross-dock facilities, bulk break centers, or package handling centers) are a principal part of the entire order fulfillment process and the foundation of a supply network. Some organizations operate both retail distribution and direct-to-consumer out of a single facility, sharing space, equipment, labor resources, and inventory as applicable. Suppliers ship truckloads of products to the distribution center, which stores the product until needed by the retail location and ships the proper quantity.
- **Major freight rail carriers** – Freight rail carriers are known to be the most efficient at moving raw materials and heavy freight over long distances. The rail network accounts for approximately 40% of U.S. freight moves by ton-miles and is largely responsible for achieving national export goals and facilitating the safe and efficient importation of goods.
- **Major motor carrier operators and dispatchers** – Trucking company dispatchers and operations managers are responsible for planning trips and maintaining communications with truck drivers; truck drivers are responsible for picking up, transporting, and delivering containers/freight.

Transit Stakeholders

Some common transit stakeholder entities include, but are not limited to:

- **State DOT transit groups** – The responsibilities of transit groups or advisory committees within state DOTs are to advise the agency on the needs of the state’s transit providers, allocation of transit funds, and rules involving public transit.
- **Regional Metropolitan Planning Organization (MPO) transit planning groups** – MPOs are regional transportation planning bodies made up of representatives from local governments and transportation authorities. MPOs are responsible for distributing federal transportation funds to their regions. MPO transit planning groups or advisory committees facilitate conversations between agencies and members of local communities to help coordinate transit planning.
- **Transit agencies at the local, intercity, and regional levels** – Transit agencies operate public transportation services in a designated service area. This service area may be confined to the jurisdiction of a single city, or spread across a larger region. Populous regions typically have several large transit agencies serving the region, often with overlapping service areas. In some situations, agencies act as both MPO and transit agency.

- **Rail, bus, ferry, private shuttle, streetcar, paratransit agencies** – Transit is not limited to bus service. Different modes of public transportation that operate within a corridor may include, but are not limited to, rail, bus, ferry, private shuttle, street car, or paratransit. These modes of transit may be operated by the same transit agency or individual agencies.
- **Transit advocacy group/citizens committee** – Some regions have established transit advocacy groups or citizens committees, which consist of citizens from a diverse set of backgrounds and interest areas in the development of transit plans and programs overseen by a transit or regional agency. These committees provide an important forum for discussion and debate about various transit programs and issues.

Incident Response Stakeholders

Some common incident response stakeholder entities include, but are not limited to:

- **State and local law enforcement** – Usually, law enforcement agencies are the first responders to arrive at the scene of a traffic incident. Jurisdiction of law enforcement agencies varies widely from state to state and even within a state. Typically, State Police and Highway Patrols have jurisdiction on State highways and county and municipal police have jurisdiction off the State highway system. On the scene of a traffic incident, the duties of these officials include securing the incident scene, providing emergency medical aid until help arrives, safeguarding personal property, conducting accident investigations, serving as incident commander, supervising scene clearance, assisting disabled motorists, and directing traffic.⁸
- **Fire and Rescue** – Fire and rescue services are provided by county and municipal fire departments. In most jurisdictions, the fire department is the primary emergency response agency for hazardous materials spills. On the scene of a traffic incident, the duties of these officials include protecting the incident scene, suppressing fires, providing emergency medical care, serving as incident commander, providing initial hazardous material (HAZMAT) response and containment, rescuing crash victims from contaminated environments, rescuing crash victims from wrecked vehicles, arranging transportation for the injured, assisting in incident clearance, and providing traffic control until law enforcement or DOT arrival.
- **Emergency medical services (EMS)** – The primary responsibilities of EMS are the triage, treatment, and transport of crash victims. In many areas, fire and rescue companies provide emergency medical services. In some areas, other agencies or private companies provide these services to local jurisdictions under contract. Typical roles and responsibilities assumed by EMS at traffic incidents include providing advanced emergency medical care; determining destination and transportation requirements for the injured; coordinating evacuation with fire, police, and ambulance or airlift; serving as incident commander for medical emergencies; determining approximate cause of injuries for the trauma center; and removing medical waste from the incident scene.
- **Towing and recovery** – Towing and recovery companies are secondary responders operating under a towing arrangement usually maintained by a law enforcement agency. On the scene of a traffic incident, their responsibilities include recovering and removing vehicles from the incident scenes; protecting victims' property and vehicles; removing debris from the roadway; and providing other services, such as traffic control, as directed or under contract.
- **HAZMAT responders** – Hazardous materials contractors are hired by emergency or transportation authorities to clean up and dispose of toxic or hazardous materials. Most common (and small quantity) engine fluid spills (e.g., oil, diesel fuel, gasoline, and anti-freeze) can be contained and cleaned up without calling hazardous materials contractors.
- **Border Patrol** – Border Patrol agents are federal law enforcement officers who are responsible for patrolling international land borders and coastal waters. Depending on the location of the

⁸https://ops.fhwa.dot.gov/eto_tim_pse/about/tim.htm.

ICM corridor, it may make sense to keep them informed of ICM activities given that they are responsible for performing traffic checkpoint operations, transportation checks, and so forth.

- **Coroner's office** – When a traffic incident results in a fatality, the coroner's office is involved to perform autopsies, pathological and toxicological analyses, and inquests relating to the investigation of deaths to determine the cause of and responsibility for the death.

Non-Motorized Roadway Users

Some common non-motorized stakeholder entities include, but are not limited to:

- **State and local bicycle and pedestrian coalitions** – Organizations that advocate for a healthy, more livable region by promoting bicycling for fun, fitness, and affordable transportation. Strategic goals may include improving the built environment for biking, walking, and transit; changing transportation policies to support an equitable, environmentally sustainable, and safe future; and prioritizing underserved communities in transportation spending and policy decisions. Organizations use advocacy, outreach, and education initiatives to achieve their missions.
- **Local and regional advocacy groups** – Advocacy groups use various forms of advocacy such as policy advocacy, community empowerment, and growing a unified statewide network of local community organizations and affiliates in order to influence public opinion and/or policy. Walking and bicycling are important transportation modes, but the needs of these non-motorized roadway users are often overlooked in transportation planning. Advocacy groups⁹ work to address this problem by advocating for the rights of pedestrians and bicyclists in their communities. Groups may focus on health equity and communities disparately impacted by pedestrian injuries and fatalities.
- **Bicycle and pedestrian planning groups at local and regional agencies** – More and more transportation agencies and MPOs (e.g., Denver Regional Council of Governments) are developing Active Transportation Plans for their region that provide an active transportation vision and implementation plan to support the development of a robust regional active transportation network.
- **Bicycle and pedestrian advisory groups/committees** – Bicycle and pedestrian planning groups at local and regional agencies often invite local community representatives (e.g., bicycle/pedestrian coalitions or advocacy groups, transit planners, etc.) to join their stakeholder committee to provide insight, feedback and local context; help guide the project teams' public outreach; provide data and information; and review materials.

Depending on the assets and characteristics (e.g., modal options, proximity to other countries, and proximity to railroads) of the ICM corridor, some of these groups may not need to be directly involved, although keeping them informed *is* recommended.

Whom Should We Reach Out to in Each Stakeholder Group?

Once the relevant stakeholders for the ICM corridor have been identified, the stakeholders will need to be further categorized into types of decisionmakers. Decisionmakers may refer to:

- **End-user Decisionmakers** – The individuals *on the corridor* that select from among different alternatives available to them; or

⁹Where the Sidewalk Starts is a blog about walkability and pedestrian policy. They compiled a list of nationwide and local pedestrian advocacy groups, available here: <http://www.wherethesidewalkstarts.com/p/pedestrian-advocacy-groups.html>.

- **Operations-Level Decisionmakers** – The entities with choices to make regarding *ICM operations and strategies to enact* during various circumstances; or
- **Program-Level Decisionmakers** – The higher level staff that *set policies and investment priorities* for an organization, entity, or group.

Because all of these decisionmakers play crucial roles in the deployment, operation, and overall success of ICM, all three types are identified, considered, and discussed below in regard to their roles as ICM decisionmakers.

End-User Decisionmakers: Individuals on the corridor who make decisions regarding travel behavior are the most direct to identify because they involve the people affected by the ICM strategies and operations. Examples of these decisionmakers include:

- **Freight** – freight vehicle operators, dispatchers, fleet managers, and supervisors;
- **Transit** – transit vehicle operators, dispatchers, fleet managers, and supervisors, as well as transit vehicle passengers and passenger car operators;
- **Incident Response** – highway patrol staff, the fire department, medical service providers, emergency vehicles and safety patrols; and
- **Non-motorized Roadway Users** – pedestrians and bicyclists.

These are the individuals whose decisions are intended to be influenced or supported by ICM and these individuals are generally the users of the facilities. In some cases, the decisionmakers may not be present on the corridor itself, as with fleet managers or supervisors who dictate what the freight and transit operators in the field must do. An initial set of end-user decisionmakers for each stakeholder group may be identified by reviewing various ICM scenarios and considering which entities would be directly affected by the ICM strategies. This may be further informed by a review of not only the candidate ICM scenarios, but also of the outcomes and results of those scenarios as implemented in real-world ICM sites (e.g., post-incident debriefing notes).

Operations-Level Decisionmakers: Another tier of decisionmakers is responsible for designing the course of action to take in any particular ICM scenario. These decisionmakers generally must have a thorough understanding of what is feasible to do, and what is acceptable/suitable given the current conditions. Traditionally, DOTs, MPOs, TMC staff, and local agencies are at the center of operations decisions because they are generally responsible for initiating route diversions, overriding traffic signal timings, and disseminating actionable traveler information. Dispatchers and fleet managers can provide the required input as to whether a specific ICM strategy would be helpful or harmful from each stakeholder's perspective, given the current state of the system, and can also indicate whether a strategy is feasible or not. An initial set of operations-level decisionmakers for each stakeholder group may be identified by reviewing various ICM scenarios and considering which entities would be best suited to evaluate the feasibility and benefit/dis-benefit associated with each choice. Identification of appropriate parties for each stakeholder group may be further informed by reviews of agency organization charts, operational decision-making processes, and/or information obtained from stakeholders themselves.

Program-Level Decisionmakers: Finally, the most abstract level of decisionmakers involves those whose input influences the overall decision regarding whether to engage in ICM planning and operations at a program level. This group can include upper management and executive-level staff at freight companies, local and regional transit agencies, state police agencies, bicycle/pedestrian planning groups at local and regional agencies, etc. An initial set of program-level decisionmakers for each stakeholder group may be identified by reviewing agency organization charts, along with the presence of any policy-forming or policy-setting entities such as steering

Freight	Transit	Incident Response	Non-Motorized
<ul style="list-style-type: none"> • Freight vehicle operator • Dispatchers • Fleet managers • Fleet supervisors 	<ul style="list-style-type: none"> • Transit vehicle operator • Transit vehicle passengers • Passenger car operators • Dispatchers, fleet managers, supervisors 	<ul style="list-style-type: none"> • Highway patrol staff • Fire department • Medical service providers • Emergency vehicles • Safety patrols 	<ul style="list-style-type: none"> • Pedestrians • Bicycles • Micro-mobility options (e.g., scooters)

Figure 8. Potential end-user decisionmakers.

committees, advisory panels, or executive boards for each stakeholder group. Program-level decisionmakers can also include even higher level policy-setting or policy-influencing entities and organizations, which may be identified by tracing funding sources for each stakeholder group.

Figures 8 through 10 present potential end-user, operations-level, and program-level decisionmakers by stakeholder group. Use Table 3 to expand or narrow the entities listed under each type in the figure, as well as to assign roles and responsibilities in the ICM project.

Who Is the Top Priority in Terms of Groups, Agencies, or People That We Need to Engage?

Program-level decisionmakers are the most critical to engage at the ICM planning stage. By convincing executive-level management of the value that ICM can bring to the freight community, transit agencies, incident responders, and/or non-motorized roadway users, program-level decisionmakers can provide top-down support and champion an ICM initiative by setting aside funding and resources. Gaining buy-in from operations-level decisionmakers can be used as a second resort. ICM initiatives often yield tangible benefits for operations-level decisionmakers, and as a result, they may advocate for ICM support from management.

Freight	Transit	Incident Response	Non-Motorized
<ul style="list-style-type: none"> •Traffic management/operations centers •Trucking associations •Port staff •Marine terminal operators •Non-vessel operating common carriers •Beneficial cargo owners •Rail company operators •Dispatchers, fleet managers, supervisors •Ocean carriers 	<ul style="list-style-type: none"> •Traffic management/operations centers •Local and regional transit agencies of all transit modes •Dispatchers, fleet managers, supervisors •Transit vehicle operators •Shuttle service providers (commuter, paratransit) •Park-and-Ride lot operators •Rideshare/taxi operators •Toll road operators 	<ul style="list-style-type: none"> •Traffic management/operations centers •Highway patrol staff •Fire and Rescue •Emergency Medical Services •Safety patrols •Towing and recovery •Emergency vehicle operators •Hazardous materials contractors •Coroners and medical examiners •Environmental, Natural Resources, Departments of Health 	<ul style="list-style-type: none"> •Traffic management/operations centers •State and local bicycle and pedestrian coalitions •Local and regional advocacy groups •Bicycle and pedestrian planning groups at local and regional agencies •Bicycle and pedestrian advisory groups/committees

Figure 9. Potential operations-level decisionmakers.

Freight	Transit	Incident Response	Non-Motorized
<ul style="list-style-type: none"> • State or regional transportation commissions • Metropolitan planning organizations • Trucking associations • Port authorities • Freight company executive and management staff • Federal Highway Administration • United States Department of Transportation 	<ul style="list-style-type: none"> • State or regional transportation commissions • Transit agencies • Metropolitan planning organizations • Shuttle service providers (commuter, paratransit) • Rideshare/taxi companies • Toll road companies • Federal Transit Administration • United States Department of Transportation 	<ul style="list-style-type: none"> • State or regional transportation commissions • State and local departments of transportation • Metropolitan planning organizations • Departments of traffic safety • State and local chiefs of police • Fire chiefs • Border patrol • Federal Highway Administration • United States Department of Transportation 	<ul style="list-style-type: none"> • State or regional transportation commissions • State and local departments of transportation • Metropolitan planning organizations • State and local bicycle and pedestrian coalitions • Local and regional advocacy groups • Bicycle and pedestrian advisory group/committees • Federal Highway Administration • United States Department of Transportation

Figure 10. Potential program-level decisionmakers.

Operations-level and end-user decisionmakers need to be engaged when deliberating ICM strategy options. This may begin during the development of the Concept of Operations for the ICM system (ICMS) and needs to continue through the detailed design of the strategies and response plans. End-user decisionmakers can provide insight into the desired actions and outcomes of an operational scenario, while operations-level decisionmakers will understand if the infrastructure, assets, and data are available to support such ICM strategies.

How Do We Identify These Entities in Our Region?

Based on interviews with non-traditional stakeholders, the following strategies for identifying non-traditional stakeholder entities in a given region can be useful.

Freight Stakeholders

- The following can be helpful starting points for outreach and engagement for these stakeholders: internal DOT committees and advisory groups related to freight and safety, freight associations, trade associations and user groups, major carriers, major freight rail operators, distribution centers, and port authorities.

Table 3. Integrated Corridor Management roles by type of decisionmaker.

Type of Decisionmaker	Who Should be Included	How to Use This List
End-User	Entities whose decisions are intended to be influenced or supported by ICM.	Use this list to ensure that proposed ICM strategies are designed to address the needs and concerns of all identified end-users.
Operations-Level	Entities who would be best suited to evaluate the feasibility and benefit/dis-benefit associated with each choice presented to travelers.	Decisionmakers on this list should be responsible for designing the course of action to take in any particular ICM scenario.
Program-Level	Entities who influence the overall decision regarding whether to engage in ICM planning and operations at a program level.	Gaining the support of these entities will result in better chances to obtain project resources such as stakeholder input, funding, data access, etc.

- Establishing freight coalitions at the DOT, holding a regional operations forum, or leveraging existing relationships that other agencies already have (e.g., MPOs, chambers of commerce) can be used to identify major freight stakeholders and subsequently engage them.
- XM/Sirius Radio (currently used by some freight operators for route information) can be used for targeted outreach to freight stakeholders.

Transit Stakeholders

- The Federal Transit Administration (FTA), internal DOT committees and advisory groups related to transit or safety, regional agencies (e.g., MPOs), and transit agencies can be a helpful starting point for identifying and engaging transit stakeholders in ICM.
- Common participants to consider include state DOT transit groups, regional MPO transit planning groups, and transit agencies at the statewide, intercity, and regional levels.
- Transit stakeholders may span several modes, including rail, bus, ferry, private shuttle, and streetcar.

Incident Response Stakeholders

- Internal DOT committees and advisory groups (or similar) related to incident management or safety can be helpful starting points for outreach and engagement for these stakeholders.
- Common participants to consider include fire departments, local police, state police, border patrol, port authorities, medical facility staff, and the coroner's office.
- MPOs or regional agencies may be useful for coordinating with responders.

Non-Motorized Roadway Users

- The following can be helpful starting points for outreach and engagement for these stakeholders: internal DOT committees and advisory groups related to bicyclists, pedestrians, or safety; state and local bicycle coalitions; local and regional advocacy groups; bicycle and pedestrian planning groups at local and regional agencies; and bicycle and pedestrian advisory groups/committees.
- Local agencies and campuses (e.g., colleges) may already have bicycle and pedestrian distribution lists or social media groups.
- Consider including both agency planners and end-users in ICM planning in order to capture (1) the real-world challenges and issues that the users face and (2) the politics and procedures of transportation planning/operations.



CHAPTER 5

Assess Potential Partners' Needs

Understanding the objectives and needs of non-traditional stakeholder groups helps to build compelling arguments for incorporating them into ICM planning.

Do We Share the Same Objectives? What Are the Main Objectives of Each Stakeholder Group?

Table 4 lists the main goals and objectives by non-traditional stakeholder group. For the freight community, travel time, a common objective of motorists, is missing from the list. The freight community is much more conscientious of travel time reliability, which is critical for on-time deliveries and pick-ups, because truck operators ultimately answer to beneficial cargo owners and other clients. Cargo type, such as perishable items, is another critical factor that depends on travel time reliability. As with freight stakeholders, travel time reliability is of utmost importance to transit stakeholders. One of the easiest ways to lose ridership is through regular schedule delays. Although safety is included on the list of goals and objectives for freight and transit stakeholders, operational processes are not as heavily dictated by this objective as they are for incident responders. Incident responder stakeholders will sacrifice mobility goals in order to protect onsite responders from harm and provide the necessary aid to incident victims. As the most physically vulnerable of the non-traditional stakeholder groups, safety is the main concern for non-motorized roadway users. One of the core strategies employed in ICM involves diverting freeway traffic to parallel arterials or to other modes when accidents, construction, or other non-recurrent obstacles degrade freeway performance. These diversions, no matter how well managed, can create high volumes of traffic at arterial intersections and/or transit stations and park-and-ride lots. Given that there is a correlation between the volume of travel through an intersection and pedestrian and bicycle safety, these additional diversions may require improvements to better protect pedestrians and bicyclists. Furthermore, traffic planning for impacted intersections may need to mitigate the impacts on pedestrian and bicycle wait times crossing in the perpendicular direction of arterial flows. Involving non-motorized roadway users in ICM planning provides opportunities to balance the transportation needs of all roadway users. Use Table 4 to design ICM strategies that position non-traditional stakeholders to receive benefits addressing their unique goals and objectives.

What Are the Major Concerns This Stakeholder Group Has in Getting Involved in ICM?

This section highlights the top priorities or concerns of each non-traditional stakeholder group regarding ICM, as reported through stakeholder interviews. These key points highlight the most significant constraints and considerations associated with this stakeholder group as

Table 4. Goals and objectives of non-traditional stakeholders.

Non-Traditional Stakeholder Group	Main Goals and Objectives	Description
Freight Stakeholders	Reliability	Freight partners are not as concerned about congestion levels as the rest of the public is. They care much more about reliability, which is needed for on-time deliveries and pick-ups, rather than speed.
	Navigability	Height restrictions, inadequate shoulder widths, inadequate turning path templates, etc., create physical accessibility barriers for trucks on truck routes and alternate routes.
	Economic Efficiency, Productivity, and Competitiveness	Reducing the cost to transport and warehouse materials increases the profit the company earns from every client. Reducing energy costs can be accomplished by consolidating shipments or maximizing transportation routes.
	Quality Customer Service	The goal of providing customers with outstanding customer service involves the ability to handle a business' transportation and logistics needs in an efficient manner that enhances the logistic firm's reputation in the industry.
	Safety	Reduce rates of crashes, fatalities and injuries associated with freight movements on the designated freight network.
Transit Stakeholders	Reliability	In order to maintain a loyal customer base, transit providers need to ensure reliable service. Passengers need to trust that their trip will be predictable or on-time.
	System Efficiency	Transit agencies want to use their resources as efficiently as possible by minimizing non-revenue miles and evolving to user needs.
	Safety	As with all other transportation agencies, safety and security of the system is a major priority for public transit providers.
	Affordability	Transit providers need to ensure that their services are priced affordably for their customer base.
	Accessibility	What types of transit services are available and where stations are located have a major impact on how frequently transit is used. Services must also be accessible for travelers with disabilities.
Incident Response Stakeholders	Responder Safety	Drivers should be required to move over and slow down when approaching traffic incident response vehicles and traffic incident responders on the roadway. When drivers learn the proper protocols when encountering emergencies on the roadway, it helps to prevent secondary incidents, including incident responder injuries and deaths.
	Safe, Quick Incident Clearance	Traffic Incident Management (TIM) partners at the state, regional and local levels are committed to achieving goals for traffic incident response and clearance times.
	Prompt, Reliable, Interoperable Communications	All traffic incident responders should receive prompt, reliable notification of incidents to which they are expected to respond. TIM partners actively partner with news media and information service providers to provide prompt, reliable incident information to the public. TIM partners encourage the development of more prompt and reliable traveler information systems that will enable drivers to make travel decisions to reduce the impacts of emergency incidents on traffic flow.
Non-Motorized Roadway Users	Safety	Safety is the main concern of non-motorized roadway users who are especially vulnerable in traffic incidents. Increasing the visibility of facility intersections, road and rail crossings; providing a buffer between side paths and vehicular traffic; enforcing speed limits and pedestrian rights in crosswalks; adding user- or motion-activated signalization can increase safety for non-motorized roadway users.
	Accessibility	Non-motorized roadway users often walk or bike as part of a multimodal trip, so accessibility to bike racks and transit stations are major deciding factors in mode choice.
	Connectivity	Non-motorized roadway users desire a network of convenient, safe, and well-designed bicycle and pedestrian facilities that link all local and regional systems and community destinations.
	Equity	Transportation needs of all motorists and non-motorists need to be balanced, otherwise pedestrians and bicyclists may experience significant delays at crosswalks.

Source: <http://smallbusiness.chron.com/goals-objectives-logistics-company-25541.html>; <https://ops.fhwa.dot.gov/publications/fhwahop16036/fhwahop16036.pdf>; and <http://www.respondersafety.com/About-Us/Key-Initiatives/National-Unified-Goal.aspx>.

they relate to ICM. For a full list of participants, please refer to **Appendix C, Stakeholder Interview Participants**. Use this list of concerns to have more informed conversations with non-traditional stakeholders. Work around the competing objectives or operational constraints that make it difficult to become more engaged in ICM. Design ICM strategies to either address the needs of non-traditional stakeholders or mitigate their concerns. Non-traditional stakeholders will be much more inclined to engage in ICM planning and design if they see potential for ICM strategies to improve their existing situation.

General Constraints

These concerns are shared across all non-traditional stakeholder groups:

- **Funding Prioritization** – Current cost-benefit project ranking methods are designed for capital improvement projects; the benefits and costs of Transportation Systems Management and Operations (TSMO) projects and ICM are not always reliably captured by these processes, making it harder to secure funding and resources for ICM at various agencies.
- **Project Continuity** – Delays related to ICM project approval and funding awards can create additional project-related problems later, as staffing turnover occurs in the interim and other demands for staff time arise.
- **Access to ICM Experts** – Contractor and consultant support for stakeholder engagement is limited.
- **Inflexible Response Plans** – A predetermined set of formal response plans can limit the ability of the ICM system to respond effectively to all possible conditions and situations.

Freight Stakeholders

The list below highlights several freight-specific operational constraints:

- **Disparate Traveler Information Sources** – Incident information and construction closure information is not readily available to freight users from a centralized on-demand information hub, which would be preferable. Instead, freight users must check multiple sources and then synthesize it themselves.
- **Inconsistent Traveler Information** – Sometimes the information provided to freight is inconsistent across different sources (e.g., dynamic message signs, 511 systems, and highway advisory radio).
- **Lack of Timely Traveler Information** – Freight stakeholders are interested in detailed real-time information about incidents, including expected clearance times, nature of the closure, and extent of current (or predicted) delays. Such information, when available, is often outdated and inaccurate.
- **Data Privacy Concerns** – Freight companies are reluctant to share information and data, out of concern that their competitors will use it to their advantage.
- **Alternate Route Limitations** – Rerouting trucks off freeways during congested periods or incident occurrences as an ICM strategy may not be worthwhile to implement or may be opposed by local jurisdictions because of inadequate shoulders and the roadway damage they can cause on arterials, in addition to the added safety risk rerouting poses to non-motorized roadway users. Unless a major incident creates a complete roadway closure, it may be simpler logistically to keep trucks (particularly oversize/overweight trucks) on the main route instead of attempting to reroute them.
- **Reluctance to Adopt New Technologies** – Freight stakeholders are generally unwilling to install additional equipment for data collection.

Transit Stakeholders

The list below highlights several transit-specific operational constraints:

- **Making a Case for ICM** – Detailed operational benefits of ICM and associated technologies (e.g., real-time vehicle occupancy counters) are not readily appreciated or well understood at transit agencies.
- **Potential for Negative Transit Impacts** – Traffic diversion associated with ICM can negatively affect transit performance if not properly managed. Some agencies have decided not to pursue such strategies as a result.¹⁰
- **ITS Investment Coordination** – Transit agencies may struggle to understand where they fit in the ITS Architecture. Transit agencies may be unable to articulate when they need upgrades to their systems for continued ICM support, and securing funds for such ongoing investment can be particularly challenging.
- **Potential Interoperability Issues** – Because FTA guidelines do not require the systems engineering process, not all transit projects follow the process, which can lead to design and interoperability issues.
- **One-directional Information Flow** – During major events and incidents, the flow of information is often one-directional, from the DOT to the transit agencies. The DOT may alert transit agencies to expect more riders, which is then used for dynamic transit vehicle routing. Some DOTs have informal agreements to notify rail operators in such situations as well.
- **Lack of ITS Infrastructure** – Better notification systems are needed to alert DOTs and local agencies when rail problems occur that will affect the roadway network (e.g., blocked road crossings, gate malfunctions).
- **Restricted Access to Roadway Assets** – Dynamic message signs are owned and operated by other agencies (e.g., state and local DOTs), and they are often unavailable for displaying transit-related messages.
- **Right-of-way Constraints** – Because transit agencies generally do not own the roadway right-of-way, it can be difficult for transit agencies to implement strategies given the number of jurisdictions and signal systems that must be coordinated with.

Incident Response Stakeholders

The list below highlights several incident response-specific operational constraints:

- **Lack of Coordination** – State police and DOT operations staff often do not coordinate with local police departments during incident situations, apart from alerting them of potential traffic diversion. Incident response teams are largely unaware of ICM strategies and activities.
- **Point of Contact Complexity** – Jurisdiction over incidents may vary by facility, such as bridges, tunnels, or standard freeway segments. In areas near international borders and ports of entry, it may be necessary to coordinate with border patrol staff in addition to state patrol and other emergency responders.
- **Procedural Conditions** – Incidents involving heavy vehicles can take longer to clear due to insurance issues. Insurance companies recommend leaving the vehicle exactly where it is after an incident (if the vehicle does not block traffic), so that evidence can be collected for the official accident report and insurance claims.

¹⁰ However, this is often not a significant issue, as projects funded by the Mass Transit Account of the Highway Trust Fund must conform with national ITS Architecture and applicable ITS standards, which includes using the systems engineering process. More information is available at https://ops.fhwa.dot.gov/its_arch_imp/policy_2.htm (accessed 2-28-2017).

Non-Motorized Roadway Users

The list below highlights several non-motorized roadway user-specific operational constraints:

- **Competing Agency Priorities** – Smaller cities tend not to have dedicated bicycle and pedestrian staff (either planning or operations), so these responsibilities become competing priorities for city traffic engineers.
- **Understanding of DOT Processes and Procedures** – Coordinating with bicyclists and pedestrians is complicated in that those users generally do not understand the politics and procedures of transportation planning/operations, and the bicycle and pedestrian planners that do understand these things are often unfamiliar with the real-world challenges and issues that those users face.
- **Competing Objectives** – Bicyclists and pedestrians are often more concerned about safety than about mobility, but ICM strategies often focus on mobility performance metrics first. Traffic diversion strategies to improve mobility for motorists can negatively impact the safety of local streets for bicyclists and pedestrians.
- **Funding Constraints** – Cities often lack the funds to invest in improvements on corridor arterials for bicycle and pedestrian users. When funding becomes short, non-motorized roadway user needs and strategies are likely to be cut from the project first.
- **Physical Limitations** – Pedestrians and bicyclists, by the nature of these modes, cannot divert nearly as far from their original routes as motorized modes can. In addition, for ICM strategies that encourage mode switches, bicycling and pedestrian modes are often poorly suited modes for most commuters for logistical/distance reasons.
- **Overlooked Needs** –
 - Bicycle and pedestrian groups may be overlooked in ICM planning because they contribute relatively short-distance trips, despite the fact that they are also crucial components of transit trips as last-mile connections.
 - Sometimes the most outspoken bicycle and pedestrian activists do not properly convey the opinion or desires of the majority of bicycle and pedestrian users.
 - Many bicycle and pedestrian incidents may currently go unreported, and as such, the gravity of bicyclist and pedestrian needs may be inadequately represented.
- **Lack of Bicyclist/Pedestrian ITS Assets** –
 - Signal coordination can often be provided with respect to one mode and travel speed, and the default is often to provide it to vehicles traveling at the speed limit, rather than to pedestrians at walking speed or bicyclists at cruising speed.
 - DOTs are unsure how to integrate historical data about bicycle and pedestrian volumes into ICM. One agency uses these data for post-incident evaluations only.
 - Automated technologies for measuring pedestrian and bicycle volumes are not yet available.
 - No known mobile apps are available that provide real-time bicycle-specific traffic alerts (such as to expect higher-than-normal arterial volumes due to a nearby freeway incident).



CHAPTER 6

Designate Performance Metrics & Data Sources

Identifying performance metrics of interest to corridor operators and stakeholder entities is key to initiating conversations for enhanced two-way data and information sharing.

Which Performance Metrics Should We Use to Evaluate How Well Our ICM Project Meets Our Goals and Objectives?

*NCHRP Web-Only Document 97: Guide to Effective Freeway Performance Measurement*¹¹ provides transportation engineers and planners help in developing and maintaining a comprehensive freeway performance-monitoring program. Multiple aspects of freeway performance were considered, including congestion, mobility, safety, operational efficiency, ride quality, environmental, and customer satisfaction. This report's guidance can lend itself to ICM projects where freeway congestion is often the driver for these types of project implementations. Adapted from *NCHRP Web-Only Document 97*, the performance measures presented in Table 5 provide a wide variety of potential performance measures that can be used to evaluate how well an ICM project meets its goals and objectives. In the table, "Quality of Service" denotes a more intuitive term for the outcome category of measures, while "Activity-Based" is more apt for the output category of measures. Quality of service (outcome) and activity-based (output) performance measures must be linked together and tied into the mission of the transportation agency.

More information is available in **Appendix D, Performance Measure Guidance**, with additional information such as description of each metric, units of measurement, geographic scale, and temporal scale. Also included are relevant statistical tests that can be used to help determine whether the changes observed are "real" or if they are simply due to chance.

Crosscutting stakeholder considerations include the following:

- Travel times are a highly relevant performance metric across most stakeholder groups.
- Post-deployment analysis of ICM outcomes (such as those after new signal strategies are implemented, or after a major incident) can help each stakeholder group appreciate the benefits of ICM and/or identify areas that continue to need improvement.
- Performance measures that provide insight into investment prioritization can be valuable to broad cross sections of stakeholders.
- Current cost-benefit project ranking methods are designed for capital improvement projects; the benefits and costs of TSMO projects and ICM are not always reliably captured by these processes, making it harder to secure funding and resources for ICM at various agencies.

¹¹ NCHRP, *Guide to Effective Freeway Performance Measurement: Final Report and Guidebook*, Document 97, 2006.

Table 5. Freeway performance measure examples.

Type of Performance Metric	Performance Metric Category	Examples
Quality of Service	Average Congestion Conditions	Travel time; travel time index; total delay (vehicles, persons); delay per vehicle; spatial extent of congestion; temporal extent of congestion; density
	Reliability	Buffer index; planning time index
	Throughput	Throughput (vehicle, persons); vehicle-miles of travel; truck vehicle-miles of travel; lost highway productivity
	Customer Satisfaction	Worst aspect of freeway congestion; satisfaction with time to make long-distance trips using freeways
	Safety	Total crashes; fatal crashes; overall crash rate; fatality crash rate; secondary crashes
	Ride Quality	Present Serviceability Rating (PSR); International Roughness Index (IRI)
	Environment	Nitrous oxides (NOx) emissions rate; Volatile Organic Compound (VOC) emission rate; Carbon Monoxide (CO) emission rate; fuel consumption per vehicle miles traveled
Activity-Based	Capacity Bottleneck	Geometric deficiencies related to traffic flow; major traffic-influencing bottlenecks
	Incident Characteristics	Number of incidents by type and extent of blockage; incident duration; blockage duration; lane-hours lost due to incidents
	Work Zones	Number of work zones by type of activity; lane-hours lost due to work zones; average work zone duration by type of activity; lane-miles lost due to work zones
	Weather	Extent of highways affected by snow, ice, rain, or fog
	Operational Efficiency	Percent freeway directional miles with equipment coverage; percent of equipment in "Good" condition; percent of total device-days out-of-service by type of device; number of service patrol assists

- Agencies and stakeholders may be more proactive and responsive about getting involved in ICM if they were positioned to receive significant benefits from the arrangement, and understood/recognized those benefits.

Which Performance Metrics Are Important to This Stakeholder Group?

Based on interviews with non-traditional stakeholders, below is a summary of some of the high-priority performance metrics expressed by each non-traditional stakeholder group.

Freight Stakeholders

Interviews with freight stakeholders across multiple states revealed unanimously that travel time reliability is the top priority of freight operators (as opposed to the travel times themselves). Anticipated or real-time delays on roadways during overnight periods, as these often disproportionately affect freight users due to their off-peak driving patterns, are useful in terms of trip planning. Truck operators can plan to leave earlier to reach their destinations if they are aware of delays on their routes ahead of time, but on-time delivery is heavily dependent on travel time reliability. Truck-specific travel times (accounting for slower travel speeds, required weigh scale stops, wait times at ports of entry, hours of service limitations, etc.) are particularly valuable to freight, although not currently available from existing trip planner applications. In terms of performance measures of interest, the Moving Ahead for Progress in the 21st Century Act (MAP-21) performance measures (freight reliability measure¹² in particular) are a priority to DOT freight planners. However, the scale of ICM is often much smaller than the scale of truck trips; thus, the performance measures provided may need to be reported for longer segments than just the ICM corridor extents. For planning purposes, freight community stakeholders are interested in the end-to-end costs of shipping between various origins and destinations by different routes and modes. Safety measures (common ones include crash severity, crash cost, and risk) for different routes and modes are useful for cost evaluations and decision support by freight stakeholders (e.g., comparing rail and highway shipping routes between Los Angeles and Chicago).¹³

Transit Stakeholders

Transit agencies are primarily concerned with improving customer service for their riders. Real-time transit-specific occupancy data, delays, travel times, travel time reliability, vehicle locations, and parking availability at transit facilities all help provide users with a better assessment of transit as an attractive travel option. Equally critical is the accuracy of the information provided to users (e.g., real-time arrival estimates, amount of remaining capacity on transit vehicles, etc.). If these forecasts are inaccurate, users may stop paying attention to these types of alerts. Similar types of real-time data can be provided to operators to monitor the effects and extents of mode shift that occurs during incident situations so as to proactively inform appropriate actions to take (e.g., dispatching additional vehicles if passenger loads are nearing capacity).

¹²<https://www.fhwa.dot.gov/tpm/rule/pm3/freight.pdf>.

¹³ Because this is a performance category of interest to freight stakeholders and because these data are often available to other ICM stakeholders (e.g., incident responders and/or transportation agencies), this may be used as an additional incentive for freight involvement in ICM planning.

In addition to real-time transit-specific data, transit planners are also interested in metrics such as parking demand at transit facilities, frequencies and causal factors for incidents that cause transit delays (e.g., traffic attempting to cut into high-occupancy toll [HOT] lanes), fare violations (e.g., places and times of the largest noncompliance rates), system health monitoring (e.g., reliability of communications and data), and cost savings achieved by ICM strategies. Cost savings that can be achieved through improved system efficiency enable transit agencies to reduce the price of services which can in turn attract more users and revenues. Impacts of an ICM project may reach beyond the arterials included in the formal project definition/scope, but because transit agencies are still likely to operate on other impacted arterials outside the project area, they need performance data for those as well.

Incident Response Stakeholders

First and foremost, incident responders are committed to safeguarding the motoring public and those responding to traffic incidents as well as those directly impacted by traffic incidents. Reducing congestion and traffic delays that occur as a result of an incident is a secondary, but still critical, priority of incident responders. Safe, quick clearance of incidents helps incident responders achieve both objectives. At an operational level, these stakeholders want any type of information that can help them reach the scene of the incident as quickly as possible while being properly prepared. Traffic management center operators who verify the reported incident may be able to provide incident responders with location information, type of incident, involvement of hazardous materials, number of vehicles involved and estimated severity level, anticipated threats or hazards that incident responders might expect, as well as the most appropriate route they can take to access the incident.

On a planning and performance measure level, TIM programs use the following measures to determine the program's effectiveness: roadway clearance time, incident clearance time, and impacts of incident management on reductions in secondary incidents. Data needed to calculate these measures typically reside in at least two separate agency databases – transportation and law enforcement. To accurately measure performance, these databases need to be integrated to include all responder activities, not just those of a single agency.¹⁴ ICM projects promote multi-agency data sharing and may be used to fill the gaps in TIM performance measurement.

Non-Motorized Roadway Users

Non-motorized roadway users are the most vulnerable of all parties on the roadway network. Safety is their utmost concern. If involved in an incident with a high-speed motorized vehicle, bicyclists' and pedestrians' chances of survival are minimal. Compared to motorists, non-motorized roadway users are especially sensitive to detours, delays, and natural elements (e.g., rain, snow, etc.). Detour routes of even a quarter mile require significantly more effort for pedestrians (especially if they have disabilities) compared with motorists. Delays at intersections where green time has been extended to flush vehicles through can incidentally expose bicyclists and pedestrians to negative environmental factors such as vehicle emissions or inclement weather. Seldom do non-motorized roadway users embark on an entire trip by foot or bicycle. Typically non-motorized transport makes up only one leg of a larger trip; therefore, delays can cause non-motorized roadway users to miss transit connections.

Currently, traveler information services (e.g., 511, roadway message signs, etc.) are tailored for motorists. Pedestrians and bicyclists tend not to check these sources before they leave or

¹⁴ <https://ops.fhwa.dot.gov/publications/fhwahop10010/presentation.htm>.

while en route to their destinations. As a result, non-motorized roadway users generally have poor situational awareness of the dynamic traffic conditions on roadways. In situations where freeway incidents cause vehicles to divert to arterial detour routes, pedestrians and bicyclists have no way of anticipating the effects that these actions will have on their safety or travel time. Non-motorized roadway users would benefit from having access to information such as changes in vehicle volumes and speeds on arterials or delays at signalized intersections so that such users can react accordingly.

Currently, automated pedestrian and bicyclist counting technology is limited. In our increasingly multimodal transportation network, added visibility of bicyclist and pedestrian activity (volumes, origins and destinations) will be valuable to bicycle and pedestrian planners. This information will help them with route planning and identifying connectivity, accessibility, and comfort factor (e.g., roadway lighting) gaps in the roadway network. Most non-fatal incidents involving bicyclists and pedestrians go unreported. Such information needs to be captured in order to identify locations of risk for non-motorized roadway users.

What Data Can Be Used to Measure Performance Metrics of Interest?

Tables 6 through 9 categorize data and performance measures desired *by* non-traditional stakeholders alongside metrics that ICM teams may wish to collect *from* non-traditional stakeholders. Data from other sources such as weather services or local agencies are not included in the tables. To use Tables 6 through 9, follow these steps:

1. Identify which data sources listed in the left column are available within your agency or partner agencies.
2. Determine the high-priority non-traditional stakeholder data elements of interest for this ICM project, using the right column for guidance.
3. Use the data sources that you can offer *to* non-traditional stakeholders as leverage in exchange for data you want *from* them.

Table 6. Operations and planning data of interest for freight performance measure calculation.

Transportation Data Desired by Freight Stakeholders		Freight Data Desired by Transportation Agencies		
<ul style="list-style-type: none"> • Truck travel times • Travel time reliability • Incident information (e.g., any official alternate truck routes, location of the incident, time, duration, nature, expected clearance times, extent of current or predicted delays) • Planned events, such as anticipated lane and roadway closures for scheduled maintenance 	<ul style="list-style-type: none"> • Lane closure information (e.g., location, time, duration, nature, and expected delay impacts) • Truck parking availability • Wait times at ports of entry • Oversize/Overweight (OS/OW) weight and permit information • Impact of traffic congestion on truck-based freight • Safety measures by route or mode (e.g., crash severity, crash cost, and risk) 	<ul style="list-style-type: none"> • Freight vehicle location data for vehicle delivery time estimates • Route optimization inputs (e.g., location of appointments, appointment time windows, load characteristics, required equipment and credentials, drivers and equipment available) • Truck origins and destinations • Economic efficiency • Environmental impacts of freight movement • Security and resilience of freight transportation 	<ul style="list-style-type: none"> • Drivers: credentials, time-of-day constraints, hours of service, pay rates • Equipment: physical capabilities and limitations, required start/end locations, preferences for use • Customers: location, time preferences, equipment requirements, company-specific assignments, costs of missed appointments • Schedule Planning: expected travel times on road segments, expected wait times, expected travel times between origin/destination pairs 	<ul style="list-style-type: none"> • Number of orders filled within scheduled time window • Number of bobtail miles • Total trip time • Total vehicle miles traveled • Stop time • Terminal queue/wait times • Fuel consumption and emissions (through application of fuel and emissions rate tables from the Environmental Protection Agency [EPA]) • Long-term freight planning data (used as inputs for optimizing roadway maintenance schedules to mitigate freight delays)

Source: FRATIS data archival plan (unpublished), stakeholder interviews.

Table 7. Operations and planning data of interest for transit performance measure calculation.

Transportation Data Desired by Transit Stakeholders		Transit Data Desired by Transportation Agencies
<ul style="list-style-type: none"> • Transit travel times • Transit vehicle location • Occupancy levels • Travel time reliability • Incidents resulting in transit delays (e.g., any official alternate transit routes, location of the incident, time, duration, nature, expected clearance times, extent of current or predicted delays) 	<ul style="list-style-type: none"> • Parking availability/demand at transit facilities, park-and-ride lots • Fare violation data • System health monitoring • Frequencies and causal factors for incidents that cause transit delays • Cost savings achieved by ICM strategies 	<ul style="list-style-type: none"> • Transit delays and causal factors • Schedule adherence data (AVL) • Automated Passenger Counter (APC) data • Transit vehicle speeds • Transit/paratransit/shuttle/ride-share routes, stops, schedules • Transfer locations • Transit fares and payment mechanisms • Transit ridership/mode share • Accident, incident, and interrupted service occurrence logs

Source: San Diego I-15 ICM AMS data collection plan, stakeholder interviews.

Table 8. Operations and planning data of interest for incident response performance measure calculation.

Transportation Data Desired by Incident Response Stakeholders		Incident Response Data Desired by Transportation Agencies
<ul style="list-style-type: none"> • Ingress/egress routes • Emergency vehicle travel times • Lane closures • Incident location (nearest postmile, direction) • Incident severity • Anticipated threats/hazards to incident responders • Personnel, vehicle, and equipment/supplies needed (e.g., towing and recovery, hazardous material spills, coroner, etc.) 	<ul style="list-style-type: none"> • Primary incident durations 	<ul style="list-style-type: none"> • Traffic management needs (e.g., temporary lane or freeway closures/traffic control, incident scene protection) • Notification of incidents that are considered hazardous to the traveling public • Estimated clearance times (for traveler information dissemination) • Number of vehicles involved in the incident, injuries and severity level • Incident classification • Cause of incident • Impacts to traffic (e.g., time of opening of individual lanes, time of opening of all lanes, time of queue clearance, etc.) • Post incident debriefs (what factors, if any, may have delayed incident clearance)
	<ul style="list-style-type: none"> • Incident response times (time to first-on-scene, departure times of first responders, etc.) • Incident clearance times • Secondary incident occurrence rates • Post incident debriefs (what factors, if any, may have delayed incident clearance) 	

Source: http://www.dot.ca.gov/trafficops/tm/docs/TIM_Guidelines_booklet_print.pdf, stakeholder interviews.

Table 9. Operations and planning data of interest for non-motorized roadway user performance measure calculation.

Transportation Data Desired by Non-Motorized Stakeholders		Non-Motorized Roadway User Data Desired by Transportation Agencies
<ul style="list-style-type: none"> • Pedestrian and bicycle-specific travel times • Prevailing vehicle volumes and speeds on arterials, for non-motorized user safety • Expected impacts to bicyclists and pedestrians during incidents (e.g., intersection delays for pedestrians and bicyclists) • Real-time estimates for risk at high frequency crash locations 	<ul style="list-style-type: none"> • Roadway comfort and environmental factors (e.g., quality of street lighting and sidewalks) • High-risk locations for non-motorized roadway users • Historical non-motorized roadway user volumes, origins, and destinations 	<ul style="list-style-type: none"> • Real-time volumes of non-motorized roadway users for decision support systems • Bicycle and pedestrian origin-destination data for better route planning (separate end points for trip segments between dwellings, transit hubs, etc.) • Historical non-motorized roadway user volumes, origins, and destinations • Incidents involving non-motorized roadway users (usually goes unreported) • Connectivity or accessibility gaps in the non-motorized roadway network

Source: Stakeholder interviews.

Engage Potential Partners

Craft effective pitches to management and non-traditional stakeholders by articulating the benefits of integration and operational opportunities in the ICM approach.

What Are the Benefits to This Stakeholder Group for Getting Involved? What Are the Benefits to Transportation Agencies for Getting This Stakeholder Group Involved?

As congestion and the number of incidents steadily increase in urban areas nationwide, the occasional collaboration and interaction among transportation agencies within a corridor is no longer sufficient to address the transportation needs of the traveling public. Although engaging additional groups of stakeholders is not easy, doing so ensures that ICM strategies are designed with all roadway users in mind.

Communicating the benefits of integration may be among the most effective approaches to encourage participation in ICM projects. ICM leaders must build a compelling case to incorporate non-traditional stakeholder groups in ICM projects by understanding the benefits to corridor operators and to the stakeholder groups themselves. Through collaboration, both corridor operators and freight stakeholders can gain insight into ICM strategies that they might not have otherwise considered. This section presents the benefits of incorporating non-traditional stakeholder groups into ICM planning into three subsections for each stakeholder group: (1) benefits for the stakeholder group themselves; (2) benefits for the transportation agencies leading the ICM project; and (3) a successful collaboration case study (provided as Exhibits 4 through 7).

Freight Stakeholders

Many urban area freight corridors are being examined as potential ICM corridors, making freight an essential ICM stakeholder. FHWA's *Integrated Corridor Management and Freight Opportunities* report¹⁵ synthesizes the following benefits that the freight community can expect to experience if they are integrated into ICM projects.

Benefits for Freight Stakeholders

On a typical corridor, work zones or congestion management strategies are not planned, executed, or communicated in an integrated fashion. The information available to the public often resides on disparate channels, making it difficult to see the complete picture. In an ICM

¹⁵ Federal Highway Administration, *Integrated Corridor Management and Freight Opportunities*. FHWA-HOP-15-018, December 2015. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop15018/fhwahop15018.pdf>.

Exhibit 4. Case study: Freight advanced traveler information system pilot projects enhance public- and private-sector information exchange.

In 2012, the Federal Highway Administration and Intelligent Transportation System Joint Program Office initiated the Freight Advanced Traveler Information System (FRATIS) project to test information technologies that would optimize the movement of containers between intermodal terminals and various inland shipping points at three different U.S. locations: Los Angeles, Dallas/Fort Worth, and South Florida. The FRATIS technologies included real-time information exchange with trading partners involving arrival, departure, and status information related to current or pending container movements. The centerpiece of the FRATIS prototypes was software that included an optimization algorithm to analyze daily container movement orders, driver information, and traffic conditions and create optimal dispatching plans.

The involvement of numerous public- and private-sector stakeholders in the FRATIS tests was important to what was achieved, and the relationships and cooperation established are likely to continue well beyond FRATIS to the benefit of each region. United States Department of Transportation (USDOT) and the development contractors expended considerable effort at the beginning of the FRATIS program to bring together drayage companies, terminal operators, port officials, and various public-sector agencies.

The FRATIS prototype tests were useful proofs of concepts that advanced the technologies. However, further enhancement (e.g., ease of use, automation, quantitative performance measurement) is needed before the prototype would be considered for continued operational use. Two additional pilot projects that will expand use of the FRATIS technologies are currently moving forward. The first involves providing incident, delay, and impact-related traveler information along the I-35 corridor in Texas to participating trucking firms that will use that information to optimize truck trips along the corridor with real-time road conditions taken into account.¹⁶ The second, Los Angeles FRATIS Phase II, looks to implement a flexible mobile application version of FRATIS, which also incorporates Connected Vehicle/Applications for the Environment: Real-Time Information Synthesis (CV/AERIS) strategies.

¹⁶ *Freight Advanced Traveler Information System (FRATIS) Impact Assessment: Final Report*. FHWA-JPO-16-225. January 25, 2016.

corridor, freight stakeholders can receive regular, validated information updates (e.g., travel times, incidents, work zones, road closures, suggested alternate routes, etc.) from operating agencies along the corridor. This provides truck operators and dispatchers with improved situational awareness of conditions on the corridor, which is especially critical as the cost of congestion is felt throughout the supply chain and eventually passed on to consumers themselves in the form of higher prices on goods and products. By becoming involved in the ICM planning process, freight stakeholders may be able to request additional information that they would like

Exhibit 5. Case study: Dallas area rapid transit leads coordination of Dallas U.S. 75 ICM project.

At the beginning of the Dallas Demonstration Site ICM project, Dallas Area Rapid Transit (DART) was the natural choice to lead the ICM coordination—it was the regional agency that managed the high-occupancy vehicle (HOV) lanes on the U.S. 75 corridor, as well as the 511 system and it had full staffing at the DalTrans TMC. One of the TMC staff was allocated to be the full-time ICM coordinator.

The Dallas site ICM program centered on the transit offerings of the DART system. The U.S. 75 corridor study area spans 28 miles and contains DART's Red Line, which expands into the Cities of Richardson and Plano and passes next to the Cities of Highland Park and University Park. In addition, the Blue Line operates near downtown Dallas and extends along the eastern edge of the corridor boundary. By providing improved multimodal traveler information, such as light-rail transit (LRT) passenger loads, LRT vehicle locations, and Red Line park-and-ride utilization on their new 511 system, U.S. 75 corridor travelers were encouraged to switch to transit during major incidents on the freeway.

DART's involvement with the ICM project revealed the potential for major benefits to transit. Historically, DART has not shared information across different transit modes (e.g., light rail, buses, and commuter rail). The U.S. 75 ICM project has sparked interest in transit data exchange. DART is now trying to take the ICM concept and develop automated response plans for situations when rail service experiences a disruption by automatically sharing information across the entire organization using a web-based tool.¹⁷

¹⁷ Interview with Todd Plesko of Dallas Area Rapid Transit, conducted on November 21, 2016 along with content from Cambridge Systematics, Inc. *Integrated Corridor Management Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas Post-Deployment Assessment Report*. FHWA-JPO-16-396. November 2016.

Exhibit 6. Case study: Genesee transportation council fosters traffic incident management as a strategic priority.

The Genesee Transportation Council (GTC), the metropolitan planning organization (MPO) for the Greater Rochester region of New York, has incorporated TIM into its planning efforts by creating an ITS strategic plan that recognizes TIM as a means of combating the region's congestion challenges. The seeds of coordination and adoption of TIM as a strategic priority were planted when New York State DOT Region 4 Operations, Monroe County DOT, and a New York State Police station were co-located in the Regional Traffic Operations Center (RTOC) in 2002. These responder and traffic operations communities quickly realized that collaboration would result in a more complete detection and response capability for both the daily routine of traffic as well as TIM.

As a result of working together, regional stakeholders have identified ways to expand and improve upon their success with the assistance and support of the MPO, which has identified multi-agency training and education targeted to local first responders as a strategic objective. This training will provide them with better information regarding the RTOC and its capabilities, reinforce the Unified Incident Command structure, help local first responders better understand the downstream impacts and safety risks associated with highway incident management activities, and educate responders on ways to minimize unnecessary disruption to the transportation system without compromising safety.

Operators and responders also quickly realized the value of different kinds of technologies. GTC has identified coordinated traffic signal timing adjustments, the installation of new highway advisory radio beacons, the addition of portable dynamic message signs, and further integration with the proposed statewide 511 system as strategic priorities to increase dissemination of traffic incident information to the general public so that drivers can avoid incident-related congestion.¹⁸

¹⁸ Genesee Transportation Council, *Intelligent Transportation Systems (ITS) Strategic Plan*, February 2011. http://www.gtcmpo.org/Docs/PlansStudies/ITS_StrategicPlanUpdate.pdf.

to receive through the ICM platform, such as information on truck-specific travel times, truck parking availability, and truck restrictions on proposed alternate routes.

With insight into accurate, up-to-date conditions along the corridor, freight operators and dispatchers can be more proactive, instead of reactive, in selecting routes, timing deliveries, and managing truck driver hours of service and available equipment. Selecting alternate routes with less congestion can also result in reduced operational costs, through fuel, driver, and equipment savings.

Exhibit 7. Case study: Developing a safe routes to school walking route map.

Phoenix, like many other communities, is working with school officials and parents to develop walking route maps to provide young students guidance on the safest routes to walk to and from school. The program makes the school trip safer by identifying the safest routes and involves a comprehensive review of the walking routes by school officials and parents to identify problem areas. The walking route plan helps identify where improvements are needed and where to place crosswalks, stop signs, and adult school crossing guards. The ultimate purpose of the walking routes is to encourage more children to walk to school and discourage parents from driving their children to school.

The school provides the walking attendance boundary map and parent volunteers review and develop the walking routes. The City provides aerial photographs, quarter-section maps, and guidelines for parents and school officials on how to conduct their reviews. The process requires parent volunteers or school officials to review the entire walking route and to identify the most desirable walking route to serve each household within the walking attendance boundary. This exercise may also involve a revision of the walking attendance boundary, if safe routes can be identified or created to serve more students.

Once the walking route maps are completed, traffic officials review the areas of concern and work with school officials to ensure the right number and placement of adult school crossing guards. The City provides final versions of the maps and maintains the computer files for the walking routes. The school officials are responsible for distributing the walking route plans to the parents at the start of the school year and when new students enroll at the school. School walking route maps are reviewed annually to identify if there are any changes to or within the school walking attendance boundary.¹⁹

¹⁹ Safe Routes to School Guide. http://guide.saferoutesinfo.org/case_studies/engineering.cfm.

Benefits for Transportation Agencies

Additional benefits can stem from the very act of collaborating with the freight community. Gaining buy-in from freight stakeholders can help ICM project leaders make a case for ICM in a region while also providing a platform for freight stakeholders to share the unique challenges that they face from a corridor user's perspective and provide input into the design of a system that can better meet their needs. Freight community knowledge of major route decision points can also help inform the geographic scope of dynamic message signs included in ICM strategies. Untapped data that can be shared *from* the freight community (e.g., truck origins and destinations, port turn times, etc.) will help to provide a more robust picture of traffic conditions within a corridor or region.

Transit Stakeholders

FHWA's *Integrated Corridor Management, Transit, and Mobility on Demand* report²⁰ states that the best way to gain buy-in and support from transit agencies is to articulate how ICM can help them achieve their transit-specific goals.

Benefits for Transit Stakeholders

ICM can improve the mobility, safety, security, quality, and efficient use of transit modes and services. ICM-transit integration can lead to enhanced data and information sharing between agencies, which is key to providing a more comprehensive picture of current network conditions. This increases the monitoring capabilities of both transit agencies and ICM corridor operators (in some cases, these roles may overlap) and can enable transit operators to better manage their resources for maximum system efficiency. For example, if a roadway incident causes motorists to switch to transit in order to avoid delays, then transit operators can make short-term adjustments in response to the incident by dispatching additional transit vehicles to accommodate the increase in demand. If long-term monitoring reveals that a certain transit route is consistently nearing maximum capacity, transit operators can make permanent changes to add additional vehicles during these recurring conditions. Transit schedules and routes can also be proactively adjusted in anticipation of planned roadway events (e.g., street closures). ICM-transit integration could increase transit ridership by enabling more efficient service, faster incident response, and improved reliability.

By disseminating comprehensive and validated data on current conditions (e.g., transit vehicle expected arrival times, travel times, delays, passenger occupancies, transfer options, etc.) in a coordinated manner, the end-users of the transportation network can benefit from better service and make more informed decisions about when and how they travel. By funding projects which improve transit travel time or accessibility, public transportation may become a more appealing travel option for roadway users, leading to increased ridership. Increased ridership leads to secondary benefits, such as increased transit service revenue, reduced vehicular demands, lower fuel consumption, and reduced emissions. In return, transit agencies may be able to increase the affordability of transit service as a result of increased revenue from additional riders.

Benefits for Transportation Agencies

On a planning level, coordinated planning between agencies can help identify opportunities where various improvements can be incorporated into the same design and construction and where key infrastructure (e.g., a communication network) can be implemented to serve multiple purposes and agencies. This proactive coordination can help eliminate redundancies and

²⁰ Federal Highway Administration, *Integrated Corridor Management, Transit, and Mobility on Demand*. FHWA-HOP-16-036, March 2016. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16036/fhwahop16036.pdf>.

minimize disruptions for construction which leads to significant cost savings. In addition, transit agencies that participate in a coordinated initiative like ICM may be able to make stronger arguments to secure funding for various improvements that provide direct travel-time benefits for transit along an ICM corridor, such as an AVL system for buses that feeds data into an ICM system. Transit priority signal systems on arterials, transit traveler information (e.g., transfer locations and times, accessibility), and integrated fare payment are examples of strategies that may be included in an ICM program.

Incident Response Stakeholders

TIM can support ICM safety and mobility objectives when incidents occur along the corridor. In a reciprocal fashion, ICM is made up of tools that can help incident responders meet their objectives for responder safety, quick incident clearance, and prompt, reliable, and interoperable communications. FHWA's *Integrated Corridor Management and Traffic Incident Management: A Primer* report²¹ describes the potential for mutual benefits resulting from ICM-TIM integration.

Benefits for Incident Response Stakeholders

Managing transportation infrastructure as an integrated system can benefit TIM programs in many ways. When incidents do occur, ICM strategies can be used to reroute and divert traffic from the incident scene to clear the way for incident responder vehicles to approach the incident more quickly and safely, respond to those in need, and transport victims in need of service to care. Motorists can be encouraged to proceed more cautiously around incident responders on scene, thereby improving the safety of the responders. By diverting roadway traffic to other facilities or modes, incident queues are reduced, which helps to minimize the potential for secondary incidents, allowing traffic flow to be restored more quickly.

Incident responder stakeholders may also benefit from the inventory of available traffic management and transportation operations infrastructure, systems, and assets. For example, 511 systems, which are usually managed by state and regional transportation agencies, may be an effective platform for incident responders to disseminate incident alerts. Traffic management centers may also be ideal places to co-locate TIM personnel. Doing so will enable traffic operators and incident responders to share traffic monitoring video feeds and coordinate a response immediately when an incident is detected.

In areas where the TIM program may not be as well established or formalized, ICM provides a platform for collaboration among TIM partners and a proving ground for coordinated incident response. Resulting relationships among TIM stakeholders can eventually be capitalized on and used to expand and formalize the TIM program beyond the ICM corridor.

Benefits for Transportation Agencies

As with the integration of freight and transit data, the integration of TIM data also helps provide an additional facet to the comprehensive situational awareness of corridor activity. Data such as anticipated incident duration, incident and roadway clearance times, occurrence of secondary incidents, and recommended alternate routes allow for more robust ICM DSS. TIM stakeholders can inform the DSS by providing valuable insights on where motorists should be rerouted when incidents occur, or what potential corridor impacts to expect from planned special events such as sporting events, concerts, major conventions, visiting dignitaries, etc.

²¹ Federal Highway Administration, *Integrated Corridor Management and Traffic Incident Management: A Primer*. FHWA-HOP-16-035, January 2016. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16035/fhwahop16035.pdf>.

By providing real-time updates regarding incident-related delays and expected roadway clearance times, motorists can better understand the incident impacts on travel times and make the appropriate alternate route or modal choices, which can help improve corridor performance.

Non-Motorized Roadway Users

Non-motorized roadway users are often an overlooked stakeholder group in ICM planning. However, there are opportunities for collaboration in ICM, as safety, the utmost concern of non-motorized roadway users, is also a high-priority ICM performance metric.

Benefits for Non-Motorized Roadway Users

Engagement with this stakeholder group can provide insights on how they can be affected by traffic management strategies that typically prioritize motorists above all others. For example, arterial diversion routes are usually programmed to give major arterials more green time in order to maximize vehicle throughput. As a result, pedestrians and bicyclists at signalized crosswalks may experience increased levels of delay which can be exacerbated by exposure to the elements (e.g., rain, snow, vehicle exhaust). To improve equity in these situations, ICM strategies involving signal coordination may be redesigned to consider pedestrian and bicyclist progression.

Awareness of heavily traveled pedestrian and bicyclist routes within an ICM corridor can help inform suitable diversion routes for vehicles or pedestrians/bicyclists. Non-motorized roadway users are limited in their ability to divert long distances – even half a mile may be considered a long distance to non-motorized roadway users. Also, pedestrians and bicyclists tend not to access traveler information sources pre-trip or en route as motorists do, so it may be easier to divert motorists instead.

Benefits for Transportation Agencies

Several ICM projects have encountered roadblocks related to the proposed strategies that may pose additional risk to these physically vulnerable roadway users. For example, in situations of major freeway congestion, ICM strategies may temporarily route traffic onto major arterial streets – the influx of vehicles with drivers who may be unfamiliar with the alternate route can cause additional safety concerns at conflict points with pedestrians and bicyclists, who may be uninformed of the sudden increase in vehicular traffic. All jurisdictions within an ICM corridor must be on board in order for an ICM project to be successful. Integrating the needs and concerns of non-motorized roadway users into ICM planning is one way to gain support from local agencies for ICM.

Increasing the convenience of non-motorized roadway usage can help reduce demand for driving. Identifying accessibility and connectivity pain points of bicyclists, pedestrians, and people with disabilities helps to develop a sustainable corridor and may also help increase transit ridership.

What Can the ICM Project Offer to This Stakeholder Group?

Interview participants representing a diverse range of stakeholders nationwide provided the following insights into opportunities for overcoming constraints and more effectively engaging non-traditional stakeholder groups in ICM planning. Agencies and stakeholders may be more proactive and responsive about getting involved in ICM if they are positioned to receive significant benefits from the arrangement, and both understand and recognize these benefits. Use the lists below to incorporate opportunities that are feasible into strategies to entice non-traditional stakeholders to participate in ICM.

Basic levels of ICM are already occurring among various agencies. During major roadway events, some agencies (e.g., state and local DOTs) proactively coordinate with transit to evaluate how transit schedules should be adjusted in response. In other circumstances, such as major transit incidents, transit agencies sometimes coordinate with local bus agencies to provide temporary replacement service. ICM projects can further develop these types of partnerships so that transit agencies do not need to limit themselves to implementing strategies within their jurisdictions or rights-of-way.

ICM Support

- **Advocate for Top-Down or Bottom-Up Support** – Political or executive-level support for ICM can encourage cooperation and participation across all stakeholder groups. Involvement and support by FHWA and FTA can help encourage participation by other stakeholders. However, one agency found that, although goals set by upper management can provide direction, the success of ICM and coordination depends on whether the operational staff feel invested in and recognize the importance of it.
- **Leverage Goals of Existing Initiatives** – Internal agency initiatives associated with inter-agency collaboration and communication can be used as motivation and justification for involvement in ICM.
- **Establish Ongoing ICM Funding** – Established sources of ongoing funds to support ICM can encourage stakeholders to commit resources and time of their own and can demonstrate that it is a long-term priority.
- **Use a Tiered Deployment Approach** – Deploying ICM in phases can help show the stakeholders the potential of ICM and motivate them to get involved in further planning in later phases, before the full deployment is complete.
- **Grant ICM Budgetary Authority to DOTs (*non-motorized roadway user-specific*)** – Granting the DOT budgetary authority for ICM implementations can allow the DOT to provide financial support to the local cities for needed improvements for bicycle and pedestrian users, in a coordinated and consistent manner across the corridor.

Stakeholder Participation

- **Bring Stakeholders to the Table** – Organizing a planning workshop where various operational scenarios are presented to stakeholders can help garner specific input from each group.
- **Involve Stakeholders Early On** – Coordinating with all stakeholders while the ICM plan is being developed (e.g., for goals, objectives, and proposed strategies), rather than simply seeking input from them during a review period for a completed plan, can help them feel more engaged and invested in the product and will allow planners to more easily implement fundamental necessary design changes in response to comments from the stakeholder groups. The various stakeholder groups may also be able to provide support for grant applications.
- **Maintain Regular Contact** – Regular meetings or conference calls (e.g., monthly, bi-monthly) can encourage involvement and identify problems early on, as can establishing a steering committee with representation from each stakeholder group. The frequency of meetings should affect the day-to-day responsibilities of each stakeholder group minimally (e.g., emergency responders must give priority to emergency situations when they arise) and the specific input needed from each group should be made clear beforehand.
- **Share Decision-Making Responsibilities** – Engaging non-traditional stakeholders and getting them to feel involved and invested may require relinquishing some influence and decision-making power to them regarding ICM. However, this also may require additional investment of time and resources from these stakeholders, such as staffing and training.
- **Conduct Incident Debriefs (*incident response-specific*)** – Debriefing meetings to discuss all factors related to an incident can help improve the efficiency of incident clearance and management.

Information Sharing

- **Refer to Successful ICM Deployments** – Examples of successful collaborations, MOUs, and arrangements between agencies for ICM can be highly informative for other agencies struggling with how to approach it. However, there must be a balance between looking to other projects for guidance and thinking critically about specific solutions and strategies that make sense for a particular agency.
- **Utilize Knowledge Base of Regional Agencies** – Having an MPO or countywide/regional agency in charge of information sharing and dissemination back-end systems may facilitate participation by all ICM parties, as other agencies (e.g., the DOTs, transit agencies) often focus on specific modes or aspects of corridor data only. Regional agencies are often more closely connected with local groups (e.g., bicycle, pedestrian, and freight groups) than the state DOT and are more likely to have done coordinated projects with these agencies in the past (which also facilitates ICM arrangements).
- **Design Comprehensive Information Sharing Platforms** – Information sharing portals that include planned event information (e.g., construction closures, major corridor events) can help all stakeholders proactively prepare and plan for the impacts and add value to the ICM system.
 - On the operations side, integrating DOT systems with transit agency systems for more seamless communication and data sharing can encourage both to coordinate their operations more often. Transit agencies can respond more flexibly and appropriately to incidents and other major roadway events if the information is provided directly to dispatchers and not just to transit vehicle operators in the field (e.g., via dynamic message signs). Real-time data can be provided to dispatchers to monitor the effects and extents of mode shift that occur during incident situations and planned roadway events, to help inform how transit schedules should be adjusted in response (e.g., dispatching additional vehicles if passenger loads are nearing capacity). Real-time transit vehicle location information and schedule adherence information can be shared with DOTs through incident management systems and public internet.
 - On the end-user side, information dissemination to the public through 511 systems can inform roadway users of their transit options during major incidents, such as transit vehicle capacity available.
- **Trade Public-Sector Data for Private-Sector Data or Functionality (*freight-specific*)** – Mobile app developers may not be interested in taking into account truck route considerations when providing rerouting guidance. However, DOTs have information that these mobile app developers want (e.g., planned lane closures) that can be used for leverage.
- **Give Freight Stakeholders Requested Information to Demonstrate Value of ICM (*freight-specific*)** – High-priority information dissemination needs of freight stakeholders include the following: real-time truck travel times, real-time truck parking availability, and freely accessible real-time truck incident and detour information that considers truck restrictions/constraints. Trucks must receive incident and rerouting information far enough in advance to act on it (i.e., before major route decision points such as alternate freeways), which may mean expanding the geographic scope of dynamic message signs included in ICM. It is even more helpful to receive the information as part of pre-trip-planning information, rather than once a vehicle is already on the road.
- **Coordinate Alternative Routes (*incident response-specific*)** – It can be helpful to establish acceptable detour routes and other procedures as part of an incident management plan in coordination with local cities and the DOT. These detour routes can be used in dynamic routing strategies to move traffic to other nearby routes, thereby reducing incident-related delays and secondary crashes.
- **Real-Time Alerts (*non-motorized roadway user-specific*)** – Twitter, 511, and arterial dynamic message signs can be good methods for reaching bicycle and pedestrian users, but they are

not ideal for two-way communication. Mobile apps may be a better option for reaching these non-motorized roadway users.

Operational Efficiencies

- **Formalize Response Plan Responsibilities** – Formal response plans can help all stakeholders know what to expect.
- **Establish Dedicated Channels of Communication (*freight-specific*)** – Although it can be impractical to have freight operations co-located with DOT operations staff, an alternative for coordination could be to establish dedicated channels of communication between the two for sharing comments and concerns.
- **Incorporate Freight Needs into Decision Support Systems (*freight-specific*)** – Decision support systems for ICM would ideally consider the type of goods being carried, given that different loads can have very different priority levels or costs associated with delays (e.g., perishables). This would be the freight analog to a decision support system that assigns different priority levels to transit vehicles according to their current occupancy levels (e.g., transit signal priority systems), where a vehicle with more occupants receives greater priority due to the calculated higher cost of delaying that vehicle based on standard value-of-time assumptions.
- **Provide Demand Management Incentives for Freight (*freight-specific*)** – Given that local agencies are generally hesitant to allow freight vehicles to be rerouted onto arterial streets, incentives for off-hours freight operations can help with ICM demand management.
- **Share Right-of-Way Access (*transit-specific*)** – Transit agencies seeking to implement Bus Rapid Transit, Bus-on-Shoulder, or bus-only lanes may be incentivized to make ICM planning and coordination a higher priority because these types of strategies can be reliant on state DOTs to facilitate deployment and formalize operational details.
- **Use Interagency Assets (*transit-specific*)** – Transit agencies are easier to incorporate into ICM planning when they already have back-end management/data systems in place and ITS infrastructure deployed in the field.
- **Select Mutually Beneficial Strategies (*transit-specific*)** – Variable speed limits may improve safety at entrances to HOT lanes, where there can be a lot of traffic (including buses) attempting to merge into a single entry point. Implementing transit signal priority on diversion routes during major incidents can increase person throughput and improve overall flow of diverted freeway traffic, which can encourage drivers to use local arterials instead of residential streets and collectors.
- **Share ITS Assets across Agencies (*incident response-specific*)** – Incident responders are easier to incorporate into ICM planning when they already have back-end coordination/data systems in place and when the DOT has incident monitoring infrastructure deployed in the field that incident responders can benefit from. Incident responders could benefit from being allowed to control DOT cameras as needed for incident monitoring, but this could conflict with the DOT and its own needs for the closed-circuit television (CCTV) systems; therefore, read-only access may be more suitable.
- **Explore Co-location Benefits (*incident response-specific*)** – Positioning DOT and incident response operations in the same facility can help foster collaboration and coordination. This can include staff from city DOTs, the state DOT, fire departments, police departments, port authorities, and medical facilities.
- **Reduce Incident Response Times (*incident response-specific*)** – ICM strategies can reduce congestion in advance of incidents, thereby improving response time to incident scenes for incident responders.
- **Improve Responder Safety (*incident response-specific*)** – ICM strategies can alert drivers to incidents ahead, thereby improving safety for responders on the scene and reducing the likelihood of secondary crashes.

- **Tie in Transit Improvements (*non-motorized roadway user-specific*)** – Bicycle and pedestrian users are often interested in seeing transit improvements as well, given that they often use transit for portions of their trips. Bike-sharing stations may be at or near transit stops, which makes both modes more convenient, attractive, and accessible.
- **Ensure Suitable Diversion Routes (*non-motorized roadway user-specific*)** – Separate diversion routes can be selected for motorists and non-motorized roadway users. In order to reduce the number of conflict points with motorists, pedestrian and bicycle activity can be shifted to lower volume streets with lower speed limits. However, if the diversion routes for non-motorized modes prove to be too far from the main route, then an ICM strategy may involve providing users with dedicated facilities (e.g., segregated bicycle lanes) on the main route to improve the safety and comfort of these vulnerable roadway users, while achieving mobility goals for motorists. Another approach would be to restrict motorist diversion routes to ones with low pedestrian and bicycle volumes.
- **Use Signal Phase Retiming (*non-motorized roadway user-specific*)** – Signal coordination may be redesigned to consider pedestrian and bicyclist progression, so as not to neglect these vulnerable roadway users at busy intersections.

What Are the Best Channels of Communication with Our Identified Stakeholder Entities?

Once non-traditional stakeholders are engaged in the ICM planning process, Tables 10 through 13 offer additional measures collected through stakeholder interviews to help to ensure continued stakeholder involvement in ICM. The strategies are organized by the decision-maker types (end-user, operations-level, and program-level) as outlined in Task 3 in Exhibit 2: Determine Potential Partners, in a format that follows the five levels of maturity in the ICM Capability Maturity Model (CMM)²²:

- **Level 1 Silo:** Agencies do not coordinate their operations with other agencies. Agencies manage their own networks independent of neighbors.
- **Level 2 Centralized:** Some agencies share data but operate their networks independently. Traffic or operational data may be shared either through an automated process or manually.
- **Level 3 Partially Integrated:** Agencies share data, and some cooperative responses are done. Data is shared through an automated feed (e.g., center-to-center [C2C]) or manually.
- **Level 4 Multimodal Integrated:** Agencies share data and implement multimodal incident response plans. Incident response uses a multimodal approach with defined detour routes.
- **Level 5 Multimodal Optimized:** Operations are centralized for the corridor, and personnel operate the corridor cooperatively. A central system is used to coordinate operations, and personnel may be co-located or work virtually with robust communication among agencies.

Decisionmaker Types

- **End-Users:** Mainly affected through technical integration, resulting in more comprehensive information dissemination.
- **Operations-Level:** Depend on interagency data and information sharing to improve the accuracy of decision support systems and performance measures.
- **Program-Level:** Require formal interagency cooperation with all operating agencies.

²² National Cooperative Highway Research Program, Advances in Strategies for Implementing Integrated Corridor Management (ICM), NCHRP Project 20-68A, Scan 12-02. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_12-02.pdf.

Table 10. Communication strategies for freight decisionmakers.

Decision maker Type	Level 1 Silo	Level 2 Centralized	Level 3 Partially Integrated	Level 4 Multimodal Integrated	Level 5 Multimodal Optimized
End-User	<ul style="list-style-type: none"> Trucking association newsletters DOT websites (for planned closures) State Patrol websites (for incident information). Dynamic message signs (DMSs) Highway advisory radio. Citizens band (CB) radio Sirius/XM satellite radio 	<ul style="list-style-type: none"> Social media (e.g., agency Twitter accounts) 511 systems Mobile apps (e.g., Google, Waze) for mode-agnostic dynamic rerouting during incidents Self-service web portal that consolidates the most up-to-date traffic information 	<ul style="list-style-type: none"> Mobile apps or truck management system modules integrating third-party truck GPS data (e.g., ATRI) for truck-specific flows, reliability, and speeds Mobile apps or truck management system modules that integrate DOT-approved truck detour routes or dynamic rerouting information for common freight destinations 	<ul style="list-style-type: none"> FRATIS applications using two-way information exchange between drayage operators (DOs) and MTOs or warehouses Centralized information hub with location-based real-time incident, delay, and closure impacts 	<ul style="list-style-type: none"> FRATIS applications with information exchange between DOs, MTOs/warehouses, and BCOs Connected trucks receive optimized route guidance directly Incorporation of destination facility wait times with roadway travel times
Operations-Level	<ul style="list-style-type: none"> Announcements, press releases from public information officers for major events (e.g., full freeway closures, long-term closures) Trucking association newsletters 511 systems State Patrol websites (for incident information) Phone calls, emails to DOT operations staff to discuss response plans, comments, concerns 	<ul style="list-style-type: none"> Self-service web portal that consolidates the most up-to-date traffic information Freight community representatives are involved with the regular updating of a static playbook of response plans State, local DOTs broadcast manually selected response plan on agencies' social media channels 	<ul style="list-style-type: none"> Truck GPS data is provided on a regular basis to State, local DOTs through data dumps or Truck Management System Application Programming Interface (API) Limited real-time data is used to inform response plan selection State, local DOTs broadcast selected response plan on agencies' social media channels 	<ul style="list-style-type: none"> Integration of Truck Management Systems and DOT operations systems Simulations of real-time truck location data and traffic conditions are used to identify the most effective response plan Freight operations-level decisionmakers receive automatic alerts with response plan instructions 	<ul style="list-style-type: none"> Alternate route guidance takes into consideration type of cargo carried (e.g., perishables) Dynamic set of response plans Connected trucks receive response plan information directly Connected vehicle data provide insights into multimodal performance measures in real time Cloud-based performance measure dashboard accessible by freight operations-level decisionmakers and DOTs
Program-Level	<ul style="list-style-type: none"> Attending existing freight, transit, incident responder, non-motorized roadway user association, coalition meetings Leveraging existing relationships that other agencies have built (e.g., MPOs, chambers of commerce) 	<ul style="list-style-type: none"> Establishing internal DOT committees and advisory groups Developing freight, transit, incident responder, non-motorized roadway user plans as a way to build relationships and trust with the stakeholders. 	<ul style="list-style-type: none"> Involving program-level decisionmakers in regional operations forums can help them understand the bigger ICM perspective, objectives, opportunities, and constraints 	<ul style="list-style-type: none"> Establishing a corridor coalition and formalizing information dissemination strategies to member agencies, emergency services, and the public 	<ul style="list-style-type: none"> Sharing operational responsibilities in a joint TMC (e.g., NITTEC) ICM corridor operations and maintenance costs are shared between corridor coalition member agencies

Table 11. Communication strategies for transit decisionmakers.

Decision maker Type	Level 1 Silo	Level 2 Centralized	Level 3 Partially Integrated	Level 4 Multimodal Integrated	Level 5 Multimodal Optimize
End-User	<ul style="list-style-type: none"> Transit agency websites Transit station posted schedules DMSs DOT websites (for planned closures) State Patrol websites (for incident information) 	<ul style="list-style-type: none"> Social media (e.g., agency Twitter accounts) 511 system (incident impacts, transit options, transit vehicle capacity, etc.) Transit station DMSs 	<ul style="list-style-type: none"> Multimodal trip planner websites or mobile apps and transit DMSs with near-real-time departure, delay information 	<ul style="list-style-type: none"> Mobile apps that allow transit users to report incidents in real time (e.g., ELERTS SafeTTC²³) 	<ul style="list-style-type: none"> Navigation apps (e.g., Go LA²⁴) that recommend various combinations of modes to satisfy users' priorities (e.g., travel time, cost, environmental impact, etc.) Multimodal navigation apps with integrated payment
Operations-Level	<ul style="list-style-type: none"> Announcements, press releases from public information officers for major events (e.g., full freeway closures, long-term closures) Ad hoc phone calls from state or local DOTs to alert transit operations-level decisionmakers to expect higher ridership levels in the event of roadway incidents Ad hoc coordination between regional and local transit agencies to provide temporary replacement service in the event of transit incidents 	<ul style="list-style-type: none"> Transit agency representatives are involved with the regular updating of a static playbook of response plans State, local DOTs broadcast manually selected response plan on agencies' social media channels Transit agencies regularly provide State, local DOTs with transit performance data, planned events and transit service disruptions 	<ul style="list-style-type: none"> Transit operators share real-time transit vehicle location and schedule adherence information with DOTs through incident management systems and public internet Limited real-time data is used to inform response plan selection State, local DOTs broadcast selected response plan on agencies' social media channels 	<ul style="list-style-type: none"> Model uses real-time transit ridership, occupancy, and vehicle location data from centralized DOT system to inform response plan selection Transit operations-level decisionmakers receive automatic alerts with response plan instructions 	<ul style="list-style-type: none"> Dynamic set of response plans Connected transit vehicles receive response plan information directly Connected vehicle data provide insights into multimodal performance measures in real time Cloud-based performance measure dashboard accessible by transit operations-level decisionmakers and DOTs
Program-Level	<ul style="list-style-type: none"> Attending existing freight, transit, incident responder, non-motorized roadway user association, coalition meetings Leveraging existing relationships that other agencies have built (e.g., MPOs, chambers of commerce) 	<ul style="list-style-type: none"> Establishing internal DOT committees and advisory groups Developing freight, transit, incident responder, non-motorized roadway user plans as a way to build relationships and trust with the stakeholders 	<ul style="list-style-type: none"> Involving program-level decisionmakers in regional operations forums can help them understand the bigger ICM perspective, objectives, opportunities, and constraints 	<ul style="list-style-type: none"> Establishing a corridor coalition and formalizing information dissemination strategies to member agencies, emergency services, and the public 	<ul style="list-style-type: none"> Sharing operational responsibilities in a joint TMC (e.g., Niagara International Transportation Technology Coalition [NITTEC]) ICM corridor operations and maintenance costs are shared between corridor coalition member agencies

²³ <http://elerts.com/elerts-develops-safettc-mobile-reporting-app-toronto-transit-commission/>.

²⁴ <https://gizmodo.com/la-has-invented-the-multimodal-navigation-app-of-my-dre-1756497278>.

Table 12. Communication strategies for incident response decisionmakers.

Decision maker Type	Level 1 Silo	Level 2 Centralized	Level 3 Partially Integrated	Level 4 Multimodal Integrated	Level 5 Multimodal Optimized
End-User	<ul style="list-style-type: none"> • Interoperable voice and data networks • Broadband emergency communication systems 	<ul style="list-style-type: none"> • Social media (e.g., agency Twitter accounts) • 511 systems • Mobile apps (e.g., Google, Waze for mode-agnostic dynamic rerouting during incidents) 	<ul style="list-style-type: none"> • Alerts from crowdsourced incident data apps (e.g., Waze²⁵, INRIX Traffic Maps & Global Positioning System [GPS]) 	<ul style="list-style-type: none"> • Apps enabling incident responders to provide data regarding real-time or planned incidents directly to citizens 	<ul style="list-style-type: none"> • Navigation apps and roadway DMSs that are updated in real-time based on incident responder activity
Operations-Level	<ul style="list-style-type: none"> • Announcements, press releases from public information officers for major events (e.g., full freeway closures, long-term closures) • State, local DOTs may elect to notify State Patrol, Border Patrol, safety agencies of incidents when they are identified on DOT-owned CCTVs • State, local DOTs may alert police departments of potential traffic diversions in the event of incidents 	<ul style="list-style-type: none"> • Incident responder representatives are involved with the regular updating of a static playbook of response plans (e.g., acceptable detour routes and other procedures) • State, local DOTs communicate response plan details directly to incident responder operations-level decisionmakers 	<ul style="list-style-type: none"> • State Patrol provides DOTs with read-only access to computer-aided dispatch (CAD) systems • State, local DOTs provide incident responders with read-only access to incident monitoring infrastructure (e.g., CCTV cameras) • Limited real-time data is used to inform response plan selection • State, local DOTs communicate response plan details directly to incident responder operations-level decisionmakers 	<ul style="list-style-type: none"> • Single incident management system and command center for both state and local police departments for improved operations • Real-time data feed from crowdsourced incident data apps (e.g., Waze, INRIX Traffic Maps & GPS) provide additional inputs into simulation models • Incident responder operations-level decisionmakers receive automatic alerts with response plan instructions 	<ul style="list-style-type: none"> • Co-locate DOT and incident response operations in the same facility to help foster collaboration and coordination • Debriefing meetings to discuss all factors related to an incident to improve efficiency of incident clearance and management • Connected incident responder vehicles receive dynamic response plan information directly • Connected vehicle data provide insights into multimodal performance measures in real time • Cloud-based performance measure dashboard accessible by incident responder operations-level decisionmakers and DOTs
Program-Level	<ul style="list-style-type: none"> • Attending existing freight, transit, incident responder, non-motorized roadway user association, coalition meetings • Leveraging existing relationships that other agencies have built (e.g., MPOs, chambers of commerce) 	<ul style="list-style-type: none"> • Establishing internal DOT committees and advisory groups • Developing freight, transit, incident responder, non-motorized roadway user plans as a way to build relationships and trust with the stakeholders 	<ul style="list-style-type: none"> • Involving program-level decisionmakers in regional operations forums can help them understand the bigger ICM perspective, objectives, opportunities, and constraints 	<ul style="list-style-type: none"> • Establishing a corridor coalition and formalizing information dissemination strategies to member agencies, emergency services, and the public 	<ul style="list-style-type: none"> • Sharing operational responsibilities in a joint TMC (e.g., Niagara International Transportation Technology Coalition [NITTEC]) • ICM corridor operations and maintenance costs are shared between corridor coalition member agencies

²⁵ <https://www.engadget.com/2017/06/05/waze-accident-data-first-responders/>.

Table 13. Communication strategies for non-motorized decisionmakers.

Decision maker Type	Level 1 Silo	Level 2 Centralized	Level 3 Partially Integrated	Level 4 Multimodal Integrated	Level 5 Multimodal Optimized
End-User	<ul style="list-style-type: none"> • Arterial dynamic message signs (DMS) • DOT websites (for planned closures) • State Patrol websites (for incident information) 	<ul style="list-style-type: none"> • Social media (e.g., agency Twitter accounts) • 511 systems • Apps that warn non-motorized roadway users of locations with high crash risk 	<ul style="list-style-type: none"> • Audible countdown signals at intersections • Apps that provide incident locations and safe pedestrian, bicyclist detour routes • Apps that indicate real-time speed and congestion levels of vehicular traffic on arterials 	<ul style="list-style-type: none"> • Audible countdown signals at intersections that adjust for pedestrian detection • Multimodal navigation apps that integrate crowd-sourced non-motorized roadway user global positioning system (GPS) data and incident reporting 	<ul style="list-style-type: none"> • Navigation apps that offer mode-specific alternate routing
Operations-Level	<ul style="list-style-type: none"> • Announcements, press releases from public information officers for major events (e.g., full freeway closures, long-term closures) • 511 systems • State Patrol websites (for incident information) • Phone calls, emails to DOT operations staff to discuss response plans, comments, concerns 	<ul style="list-style-type: none"> • Bicycle and pedestrian advocacy/advisory group representatives are involved with the regular updating of a static playbook of response plans • State, local DOTs broadcast manually selected response plan on agencies' social media channels 	<ul style="list-style-type: none"> • State, local DOTs receive data feeds from mobile apps that track real-time pedestrian and bicyclist movement (e.g., LiveTrekker, Strava Metro) • Limited real-time data is used to inform response plan selection • State, local DOTs broadcast selected response plan on agencies' social media channels 	<ul style="list-style-type: none"> • Model uses real-time non-motorized roadway user GPS data to inform response plan selection • Non-motorized roadway user operations-level decisionmakers receive automatic alerts with response plan instructions 	<ul style="list-style-type: none"> • Connected non-motorized roadway users receive dynamic response plan information directly • GPS tracking from connected non-motorized roadway users provides insight into real-time non-motorized roadway user volumes, delays • Cloud-based performance measure dashboard accessible by non-motorized roadway user operations-level decisionmakers and DOTs
Program-Level	<ul style="list-style-type: none"> • Attending existing freight, transit, incident responder, non-motorized roadway user association, coalition meetings • Leveraging existing relationships that other agencies have built (e.g., MPOs, chambers of commerce) 	<ul style="list-style-type: none"> • Establishing internal DOT committees and advisory groups • Developing freight, transit, incident responder, non-motorized roadway user plans as a way to build relationships and trust with the stakeholders 	<ul style="list-style-type: none"> • Involving program-level decisionmakers in regional operations forums can help them understand the bigger ICM perspective, objectives, opportunities, and constraints 	<ul style="list-style-type: none"> • Establishing a corridor coalition and formalizing information dissemination strategies to member agencies, emergency services, and the public 	<ul style="list-style-type: none"> • Sharing operational responsibilities in a joint TMC (e.g., Niagara International Transportation Technology Coalition [NITTEC]) • ICM corridor operations and maintenance costs are shared between corridor coalition member agencies

Take the following steps to make good use of Tables 10 through 13:

1. As the ICM leader, assess which level of maturity your communication methods with this non-traditional stakeholder group ranks now for each decisionmaker type.
2. Identify where you want your communication maturity level to be in a set period (e.g., 5 years). The maturity levels between where you are now and where you want to be are the improvements that are needed to reach your desired maturity level.
3. Start making plans for incremental growth.

How Do We Use the Content in This Guidebook to Create a Strong Argument to Management and to This Stakeholder Group So They Can Be Effective Partners?

Understanding the benefits of incorporating non-traditional stakeholders into ICM planning is the first step. The next step is to present a strong case to management on why to involve non-traditional stakeholders in ICM planning. Once management is on board, engage non-traditional stakeholders themselves by emphasizing the win-win scenarios that can result from collaboration in the ICM approach.

One method for getting the message across in a timely and effective way is to develop a 2-minute elevator pitch for each audience (i.e., management and a specific non-traditional stakeholder group). Use these guidelines to create a compelling pitch:

- **Answer “What’s in it for Me?”** – Know what is motivating your audience. Before you can make a connection with your audience, you need to know who they are and what they care about, as it relates to your pitch. It needs to be clear to your audience what they will be getting out of this arrangement in exchange for their time and resources. If you are pitching to management, they are going to care a lot about how this will help them achieve their ICM goals or other internal initiatives. If you are pitching to freight stakeholders, they are going to care about how this approach will help them streamline their operations and become more competitive in the industry. If you are pitching to transit stakeholders, they are going to care about how this approach will help them improve their service and attract more ridership. If you are pitching to incident response stakeholders, they are going to care about how this approach will help them improve incident response times and the safety of their responders. If you are pitching to non-motorized stakeholders, they are going to care about how this approach will help keep bicyclists and pedestrians safe on the roads and how ICM will help further their vision for a robust regional active transportation network.
- **Provide Statistics** – The more trustworthy you can prove to be, the more likely your audience is going to buy in to what you are pitching. Back up your argument with statistics on benefits from other successful collaborations. Share testimonials or a brief story of how ICM has affected other members of the freight community, transit agencies, incident responders or active transportation community. If you are listing travel time savings as a potential benefit, how much time have other freight stakeholders, transit agencies, or incident responders saved after adopting an ICM approach? If you are listing increased accessibility as a potential benefit, how many motorists chose to switch to non-motorized modes after adopting an ICM approach? If the benefit to management is bringing another perspective to the table, what input was provided from the freight community, transit stakeholders, incident responders, or non-motorized roadway users that you were not previously aware of?
- **Offer a “Clear Ask”** – If your audience understands what you are specifically asking them to do, it will be easier for them to know if it is feasible for them to participate, or whether there is someone within their community who could fill the role. Are you asking them to attend regular meetings? If so, how frequent will the meetings be? Are you asking them to spend

money on new equipment? If so, how much do you anticipate the cost to be? Are you asking them to provide data or test out a new mobile app feature? If so, what type of data or feedback do you need?

- **Use Emotion** – Use emotion to connect with your audience. Share a story that relates to your audience in a personal way. For example, if you are campaigning for the reduction of late freight shipments, you may want to connect that to supermarkets having a low supply of milk. You may want to connect improved schedule adherence to disadvantaged communities missing the bus to go to work, or faster incident response times to the number of lives lost because they did not make it to the hospital in time. If you are campaigning for the safety of bicyclists and pedestrians, you may want to connect that to a local high-profile bicyclist/pedestrian incident.

Freight Stakeholders

Examples 1 and 2 are sample pitches to involve freight stakeholders in ICM planning and can be used as models. The content of these two examples are color-coded to map to each pitch component.

Example 1: Pitch to Management – Why We Need to Involve Freight Stakeholders in ICM Planning

Audience: Jane, Director of the ICM program at the State DOT

Pitcher: John, Project Manager of a specific ICM project

Offer a “Clear Ask”	[Hi Jane, I am here today to talk to you about establishing a freight advisory council for this department of transportation and I want you to be the Chair of the council, because of your expertise in ICM. This freight-focused council will help us collect input on the needs and concerns from the freight community, which are significantly different from the other motorist groups that we collaborate with. As you are well aware, we received significant backlash from the last ICM project when we provided the same alternate routes for freight vehicles, which inadvertently caused delays on the local arterial when a multi-trailer truck got stuck at an intersection with insufficient turning radius to accommodate the vehicle. That time the negative impact was only increased delay, but I am afraid that next time something worse might happen, like collisions with bicyclists or pedestrians. National crash statistics collected by the National Highway Traffic Safety Administration show that from 2015 to 2016, there was a 13% increase in the number of pedestrians and bicyclists killed in a collision with a large truck. ²⁶
Answer “What’s in it for Me?”		
Use Emotion	[By establishing this freight advisory council with you as the Chair, we are making a public statement that we want to get ahead of this problem and incorporate the needs of all stakeholder groups into the design of a comprehensive ICM approach. I do not anticipate the council meeting more than once a month and I will help recruit members of the freight community to participate. So, do I have your commitment?
Provide Statistics		
Answer “What’s in it for Me?”	[
Offer a “Clear Ask”		

Example 2: Pitch to Stakeholders – Why It is Beneficial for You to Get Involved in ICM Planning

Audience: Joe, CEO of ABC Trucking

Pitcher: John, Project Manager of a specific ICM project

Offer a “Clear Ask”	[Hi Joe, I am here today to talk to you about joining our State’s freight advisory council. We are embarking on an integrated corridor management project along this corridor and would
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²⁶ <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812497>.

really value your input on the needs and concerns of the freight community, given that the bulk of your truck trips use this corridor. Integrated corridor management is an approach to coordinating day-to-day operations along heavily traveled corridors so as to increase operational efficiencies. The San Diego integrated corridor management pilot demonstration resulted in annual travel time savings of over 250,000 person hours and annual travel time variability improvements of more than 150,000 hours.²⁷

Offer a "Clear Ask"

Provide Statistics

So let me tell you how getting involved can benefit your business. I know that your company was founded by your great-grandfather and has had a reputation for never having had a serious incident in its entire 122 years, until last year when one of your trucks overturned and caught fire on the highway because the detour route was not signed properly. We want to help you make sure this does not happen again so that you can maintain your reputation for safety and efficiency. By acting as a representative for the freight community and helping to spread the word on what public-sector resources are available, you will be acting as a leader and role model in the freight community.

Use Emotion

Answer "What's in it for Me?"

By reviewing the integrated corridor management strategies that we are considering for implementation, you can inform us if they would be useful for your drivers and dispatchers. For example, if we provide information such as planned closures or incident occurrences along this corridor, how would you use this information to ensure that your drivers minimize the time they spend sitting in traffic and have better situational awareness of incidents on their routes?

Offer a "Clear Ask"

Answer "What's in it for Me?"

What I need is for you or someone in your company who is very familiar with your internal operations to attend these monthly freight advisory council meetings and provide insight on the freight perspective along this corridor. Can I count on your participation?

Offer a "Clear Ask"

Transit Stakeholders

Examples 3 and 4 are sample pitches to involve transit stakeholders in ICM planning and can be used as models. The content of these two examples are color-coded to map to each pitch component.

Example 3: Pitch to Management – Why We Need to Involve Transit Stakeholders in ICM Planning

Audience: Jane, Director of the ICM program at the State DOT

Pitcher: John, Project Manager of a specific ICM project

Hi Jane, I am here today to talk to you about reaching out to our regional transit agency, ABC Transit, as a partner for this ICM project. ABC Transit recently conducted a survey assessing transit service performance in the region. This survey revealed that riders from disadvantaged communities listed on-time performance as the most important attribute of transit service. For 50%²⁸ of peak-period riders, transit is their main way of getting to work. If they miss their bus or their transfer and arrive at work late, it could be grounds for termination in many blue-collar industries. ABC Transit has been brainstorming solutions to improve their schedule adherence and travel time reliability to address this issue.

Offer a "Clear Ask"

Provide Statistics

Use Emotion

²⁷ https://rosap.nhtl.bts.gov/view/dot/32035/dot_32035_DS1.pdf.

²⁸ This is a fictional statistic for the purpose of this elevator pitch.

Offer a "Clear Ask"	[Our ICM strategy currently centers on diverting freeway traffic onto major arterials in the event of a major incident. I am concerned that the major arterials will not have the capacity to support diverted freeway traffic. I believe that by bringing ABC Transit to the table, we can come up with a mutually beneficial solution. Along major diversion routes, which already contain underutilized park-and-ride lots, it may make sense for us to implement bus rapid transit service, bus-only lanes, or transit signal priority to incentivize mode switch. Not only would this improve schedule adherence for normal transit service, but by asking ABC Transit to share real-time data on their vehicle locations and capacities, we could also increase person throughput during major incidents or special events by notifying ABC Transit to dispatch additional vehicles as needed. So, are you open to discussing partnership opportunities with ABC Transit?
Answer "What's in it for Me?"		
Offer a "Clear Ask"		

Example 4: Pitch to Stakeholders – Why It is Beneficial for You to Get Involved in ICM Planning

Audience: Joe, Director of ABC Transit

Pitcher: John, Project Manager of a specific ICM project

Offer a "Clear Ask"	[Hi Joe, I am here today to talk to you about partnering with us on an integrated corridor management project along this corridor. I see many opportunities for collaboration between our agencies. We have similar goals to provide fast, reliable transit service through this corridor on a normal basis, but especially when major events such as incidents or special events cause abnormal congestion levels on the freeway. Integrated corridor management is an approach to coordinating day-to-day operations along heavily traveled corridors so as to increase operational efficiencies. The San Diego integrated corridor management pilot demonstration resulted in annual travel time savings of over 250,000 person hours and annual travel time variability improvements of more than 150,000 hours. ²⁹
Provide Statistics		
Use Emotion	[We know that transit is a lifeline for many people who cannot afford to own a vehicle. Given that your agency does not own the right-of-way on this corridor, we feel partially responsible for your agency's poor on-time performance metrics. To combat this, we are working on strategies to reduce the number of passenger vehicle trips along the corridor. To achieve this, we want to make transit a more desirable mode of transportation. We want to begin by helping you implement a solution such as bus-only lanes so that your riders will no longer miss their transfers or be late to work. We want to use funding from this ICM project to help you maintain your reputation as a reliable mode of transportation with travel times that are competitive with passenger vehicles.
Answer "What's in it for Me?"		
Offer a "Clear Ask"	[In return, I am hoping that you will be interested in helping us design a transit mode switch strategy for motorists that uses the benefits of the bus-only lane. We would require you or someone in your company who is very familiar with your internal operations and data systems to attend our ICM planning sessions, see the project through implementation, and be willing to help operate and maintain the transit elements of the ICM system. We have several potential ICM funding sources, but as a partner, you would need to be prepared to contribute a percentage of funds toward the project. Can I count on your partnership?

Incident Response Stakeholders

Examples 5 and 6 are sample pitches to involve incident response stakeholders in ICM planning and can be used as models. The content of these two examples are color-coded to map to each pitch component.

²⁹ https://rosap.ntl.bts.gov/view/dot/32035/dot_32035_DS1.pdf.

Example 5: Pitch to Management – Why We Need to Involve Incident Response Stakeholders in ICM Planning

Audience: Jane, Director of the ICM program at the State DOT

Pitcher: John, Project Manager of a specific ICM project

Hi Jane, have you ever had a family member who needed to be rushed to the hospital and on the way there, every red light seemed to last forever? Well, I am here to talk to you today about setting up some workstations in our traffic management center for highway patrol, police department, and fire department staff as part of our ICM strategy along this corridor. Having a single command center allows us to share ITS assets such as our automatic incident detection system and CCTV video feeds for confirming incident details, establish suitable detour routes more efficiently, and ultimately reduce response times because every extra second counts.

Use Emotion

Each month, highway patrol responds to over 200 incidents along our proposed ICM corridor. The likelihood of a secondary crash increases by 2.8% for each minute the primary incident continues to be a hazard, increasing the risk to driver and responder lives, and making it even more difficult for responders to get to and from the scene.³⁰ ICM can improve the process for identifying and communicating with the appropriate points of contact at each agency in a variety of situations, as well as developing a predetermined set of procedures to be followed by each agency in a given situation as agreed on by all parties in advance. By coordinating operations between our department of transportation and incident responders, not only can we reduce incident-related delays, but we can improve the safety of our responders in the field and reduce the number of secondary incidents by reducing congestion around the incident location.

Provide Statistics

Answer “What’s in it for Me?”

I am asking you to set aside funding to accommodate more staff in our traffic management center and invite incident responders to the table to help develop response plans for different operational scenarios along this ICM corridor. So, do I have your commitment?

Offer a “Clear Ask”

Example 6: Pitch to Stakeholders – Why It is Beneficial for You to Get Involved in ICM Planning

Audience: Joe, Chief of ABC Highway Patrol

Pitcher: John, Project Manager of a specific ICM project

Hi Joe, how many times have you felt unsafe at the scene of a traffic incident because the drivers passing by were too distracted by the incident to pay attention to the road? I am here today to talk to you about working with our state DOT to come up with ways to reduce response times and improve the safety of your responders, as well as other emergency responders. We are embarking on an integrated corridor management project along this corridor and see many opportunities for coordinating our operations. Integrated corridor management is an approach to coordinating day-to-day operations along heavily traveled corridors in an effort to increase operational efficiencies. The San Diego integrated corridor management pilot demonstration resulted in annual travel time savings of over 250,000 person hours and annual travel time variability improvements of more than 150,000 hours.³¹

Use Emotion

Provide Statistics

So let me tell you how getting involved can benefit the highway patrol. We can restructure our traffic management center to provide workstations for highway patrol, police department,

Answer “What’s in it for Me?”

³⁰ <https://ops.fhwa.dot.gov/publications/fhwahop10010/presentation.htm>.

³¹ https://rosap.ntl.bts.gov/view/dot/32035/dot_32035_DS1.pdf.

Answer "What's in it for Me?"

and fire department staff. Here, your staff will have access to our automatic incident detection system and our CCTV video feeds. When an incident occurs, we will all hear about it at the same time. Being in the same room will make it easier to establish a safe route for emergency responders, while our traffic operations staff posts suitable detour routes for the traveling public on our dynamic message signs. This can help your staff shave valuable seconds off response times and give you the tools to improve the safety of your responders in the field.

Offer a "Clear Ask"

If you are interested in coordinated operations, I need two things from you. First, I need you to assign someone to work out of our traffic management center. Then I need you or someone on your team who is very familiar with your internal operations to collaborate on the design of our ICM system and response plans. This may require data sharing between our agencies. I will also be reaching out to other incident responders that operate along this corridor. Can I count on your participation?

Non-Motorized Roadway Users

Examples 7 and 8 are sample pitches to involve non-motorized roadway users in ICM planning and can be used as models. The content of these two examples are color-coded to map to each pitch component.

Example 7: Pitch to Management – Why We Need to Involve Non-Motorized Stakeholders in ICM Planning

Audience: Jane, Director of the ICM program at the State DOT

Pitcher: John, Project Manager of a specific ICM project

Use Emotion

Provide Statistics

Use Emotion

Offer a "Clear Ask"

Answer "What's in it for Me?"

Offer a "Clear Ask"

Hi Jane, as you are well aware, last year was the grand opening of the transit center that connected two separate light rail lines for more accessible transit access throughout the region. We considered this project a huge success because of the spike in ridership experienced on both light rail lines. Unfortunately, the additional foot traffic around the transit center has resulted in a higher bicycle and pedestrian incident rate compared to our statewide averages, including that hit and run last week that ended up killing a high school student on his way home. Hit-and-run accidents, particularly those occurring in urban areas, are becoming increasingly more dangerous for pedestrians and bicyclists. Large cities like New York City reported a 37% spike in the number of fatal hit-and-run accidents between 2014 and 2016.³² I know that this transit center will play a big role as an alternative mode for motorists in our proposed ICM system. As such, we anticipate vehicular traffic to increase in and around the center during major incidents or special events. I am concerned how this will impact the safety of bicyclists and pedestrians in the area.

I am here today to talk to you about establishing a permanent bicycle and pedestrian advisory group for our State DOT, which we would use for this ICM project we are embarking on. This advisory group should include active transportation representatives from local agencies and metropolitan planning organizations, as well as state, regional and local bicycle/pedestrian coalitions and advocacy groups. By bringing these stakeholders to the table, they will be able to provide insight, feedback, and local context in relation to the ICM strategies we want to implement so that we can find ways to address their needs while still achieving our mobility goals. We can ask them to guide our team's public outreach efforts to the bicycle and pedestrian community, a community that we have historically had very little collaboration with. I do not anticipate the advisory group meeting more than once a month, and I will help recruit members of the active transportation community to participate. So, do I have your commitment?

³² <https://www.peoplepoweredmovement.org/>.

Example 8: Pitch to Stakeholders – Why It is Beneficial for You to Get Involved in ICM Planning

Audience: Joe, President of ABC Advocacy Group

Pitcher: John, Project Manager of a specific ICM project

Hi Joe, I am here today to talk to you about joining our State's newly established bicycle and pedestrian advisory group. I know that your son was a classmate of the hit-and-run victim last week and I want you to know that we want to do everything in our power to make sure that an incident like that does not happen again. We are embarking on an integrated corridor management project along this corridor and would really value your input on the needs and concerns of the active transportation community, particularly given that, since its opening, the transit center on this corridor has attracted much more foot traffic. Integrated corridor management is an approach to coordinate day-to-day operations along heavily traveled corridors in an effort to increase operational efficiencies. Although integrated corridor management pilot sites have demonstrated travel time savings and travel time variability improvements, the impacts to the safety of motorists and non-motorists are not very well understood.

Offer a "Clear Ask"

Use Emotion

Offer a "Clear Ask"

Provide Statistics

Improving the safety of bicyclists and pedestrians is one of our biggest objectives for the integrated corridor management project along this transit-centric corridor. We need input from the active transportation community so that we can design effective solutions that will make an impact that we can measure and improve on. We also want to pilot new technology that we want to develop, with members of your advocacy group, such as a mobile app that disseminates real-time alerts to bicyclists and pedestrians the way 511 does for motorists.

Answer "What's in it for Me?"

We think that any incident involving a pedestrian or bicyclist is unacceptable. With your partnership, I know we can find a way to reduce the number of pedestrian and bicyclist incidents not only along this corridor, but statewide. What I need is for you and members of your affiliates to attend these monthly bicycle and pedestrian advisory group meetings and provide insight on the non-motorized roadway user perspective along this corridor. Can I count on your participation?

Offer a "Clear Ask"



CHAPTER 8

Develop ICM System Concept

Develop an ICM system concept by designing ICM strategies and response plans that incorporate the needs of all stakeholder groups.

Which ICM Strategies Will Help Us Achieve Our Goals for This ICM Project?

ICM combines two fundamental concepts: active management and integration. Active management involves monitoring and assessing the performance of the system and dynamically implementing actions in response to fluctuations in demand. In an ICM corridor, all individual facilities must be actively managed so that operational approaches can be altered in real time in response to an event anywhere on the system.³³

The USDOT's ICM initiative aimed to pioneer innovative multimodal and multijurisdictional strategies—and combinations of these strategies—to help manage congestion in our nation's busiest corridors. Table 14 details the main components of the Demonstration Sites' ICM deployments along U.S. 75 in Dallas and I-15 in San Diego (initially introduced in Table 1). Use Table 14 to model your ICM strategies after these two Demonstration Sites if the objectives of those ICM projects are relevant to yours.

There is no standard set of ICM strategies to include in an ICM project. Ultimately, the ICM strategies chosen for a specific corridor will depend on factors such as traffic patterns, available assets, and agency collaboration. Table 15 presents a sample of ICM strategies that can be used to mitigate an array of corridor deficiencies. Potential mitigation strategies are not limited to addressing a single observed deficiency – strategies can be designed to address multiple issues.

Recurring congestion refers to congestion caused by routine traffic volumes in a typical environment – no unusual circumstances have occurred. Non-recurring congestion describes unexpected or unusual congestion caused by an event that was unexpected and transient relative to similar days. For example, non-recurring congestion can be caused by lane-blocking events (e.g., accidents, disabled vehicles, debris in the roadway, construction, etc.), inclement weather, or significant increase in traffic volumes in comparison to typical traffic volumes for that particular location.³⁴ An expanded version of this table is available in **Appendix B, Overview of Integrated Corridor Management**, with additional information such as a description

³³ Federal Highway Administration, Integrated Corridor Management and Traffic Incident Management: A Primer, FHWA-HOP-16-035. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16035/fhwahop16035.pdf>

³⁴ USDOT ITS Joint Program Office, Integrated Corridor Management Concept Development and Foundational Research Phase 1 – Concept Development and Foundational Research, FHWA-JPO-06-034. Available at: https://ntl.bts.gov/lib/jpodocs/repts_te/14273_files/14273.pdf.

Table 14. Strategies included in demonstration sites' Integrated Corridor Management deployments.

U.S. 75 ICM Strategies	I-15 ICM Strategies
<ul style="list-style-type: none"> • Providing improved multimodal traveler information (pre-trip, en-route), such as: <ul style="list-style-type: none"> » New 511 system (real-time information, including traffic incident information, construction information, traffic speeds, light-rail transit (LRT) passenger loads, LRT vehicle locations, Red Line park-and-ride utilization) » My511 e-mail alerts » ICM dynamic message signs (DMS) messages » Social media » Dallas Area Rapid Transit (DART) data feeds for third-party application development • Developing preapproved ICM system (ICMS) response plans • Developing a decision support system (DSS) to support ICM strategy identification and selection • Diverting traffic to key frontage roads and arterials (Greenville Ave.) with coordinated and responsive traffic signal control • Encouraging travelers to use transit during major incidents on the freeway 	<ul style="list-style-type: none"> • Active DSS • Coordinated incident management • Freeway coordinated ramp metering • Actionable traveler information (en-route and pre-trip via DMS, a new 511 app, and other commercial sources) • Upgrades to selected traffic signal systems (new traffic signal coordination timings, responsive traffic signal control) • Alternate route wayfinding signs

Source: USDOT Office of the Assistant Secretary for Research and Technology, Integrated Corridor Management Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas Post-Deployment Assessment Report, FHWA-JPO-16-396. Available at: <https://ntl.bts.gov/lib/60000/60400/60490/FHWA-JPO-16-396.pdf>; USDOT Office of the Assistant Secretary for Research and Technology Integrated Corridor Management Analysis, Modeling, and Simulation for the I-15 Corridor in San Diego, California Post-Deployment Assessment Report, FHWA-JPO-16-403. Available at: <https://ntl.bts.gov/lib/61000/61100/61131/FHWA-JPO-16-403.pdf>.

of each strategy and potential benefits that can stem from implementing each strategy. To use the expanded version of Table 15, take the following steps:

1. Identify the facility type of interest (freeway or arterial).
2. Identify the problem area (safety/crashes, non-recurring congestion, or recurring congestion).
3. Assess the relevance of the expected benefits (presented in **Appendix B, Overview of Integrated Corridor Management**).
4. Determine the feasibility of the strategies of interest.

Which ICM Strategies Will Help This Stakeholder Group Achieve Their Objectives?

This section introduces several ICM strategies designed to generate mutual benefits for ICM agencies *and* the non-traditional stakeholder group ICM agencies aim to involve. For each ICM strategy below, the main goals and objectives (as were presented in Table 4) that this strategy can help address are listed.

Freight Stakeholders

Although ICM is often thought of as a combination of strategies to improve corridor mobility and performance in general, several freight-specific benefits are sensitive to the particular needs, priorities, and constraints of heavy vehicle fleet managers and operators. With the availability and integration of data sources between freight stakeholders and DOTs, several examples of ICM strategies with freight-specific benefits may become feasible:

- **Traffic Information for Route Planning** – Through close system integration with real-time traffic condition data sources, freight dispatchers and fleet managers can more effectively route their vehicles around anticipated congestion and modify driver departure times to minimize overall vehicle hours traveled and optimize delivery times. – *Potential benefits toward travel time reliability and economic efficiency objectives.*

Table 15. Potential integrated corridor management strategies for freeways and arterials.

Facility Type	Type of Observed Deficiency	ICM Strategy Examples
Freeways	Safety/Crashes	Improved dynamic corridor ramp metering algorithms; queue warning; improved decision support systems and incident response plans; media and social media alerts
	Non-Recurring Congestion	Dynamic high-occupancy vehicle conversion; speed harmonization/variable speed limits; dynamic rerouting; media and social media alerts
	Recurring Congestion	Lane use signals/dynamic lane management; dynamic pricing; dynamic junction control; media and social media alerts
Arterials	Safety/Crashes	Emergency vehicle signal preemption system; automatic work zone information system; improved decision support systems and incident response plans; media and social media alerts
	Non-Recurring Congestion	Predictive traveler information; increased transit and parking capacity; dynamic lane reversal; media and social media alerts
	Recurring Congestion	Coordination of freeway ramp metering and arterial signal control; adaptive traffic signal control; transit signal priority; media and social media alerts

- **Maintenance and Construction Planning** – Planned events, such as anticipated lane and roadway closures for scheduled maintenance, can be considered by freight dispatchers and fleet managers when driver plans are developed each day, such that the trip performance and delivery impacts of those closures can be minimized. Long-term freight planning data can also be used as inputs for optimizing maintenance schedules, so that closures on peak freight routes and travel days can be minimized or anticipated and mitigated. – *Potential benefits toward travel time reliability, economic productivity, and quality customer service objectives.*
- **Dynamic Routing around Active Incidents** – Truck alternative routes are limited and can be challenging to locate during incident situations. With ICM, integration between truck operators and traveler information systems becomes possible, allowing specific truck route detour guidance to be directed toward relevant freight vehicle operators only. Additionally, integration between DOTs and local agencies helps ensure that the active detour truck routes are prepared to handle the rerouted traffic (e.g., through signal retiming, local traffic control, and activation of arterial dynamic message signs for guidance). – *Potential benefits toward navigability and travel time reliability objectives.*
- **Improved Performance through Advanced Signal Coordination** – With advanced detection technologies deployed as part of an ICM program, arterial traffic signals can anticipate approaching freight vehicles and respond accordingly for optimized performance. With freight Eco-Driving, an equipped signal communicates its upcoming phase changes to approaching drivers, who can then adjust their speeds to conserve momentum/fuel and minimize the number of stops that are performed. – *Potential benefits toward economic efficiency and economic competitiveness objectives.*
- **Real-Time Predictions for Freight Deliveries/Arrivals** – When freight vehicle location data are integrated with real-time predictive models of future performance implemented with ICM programs, more accurate estimates for vehicle delivery times are possible. These data can be used by logistics companies to properly anticipate vehicle arrivals at terminals or warehouses, or to provide customers with more precise information about the progress of their shipments. – *Potential benefits toward quality customer service and economic competitiveness objectives.*

Transit Stakeholders

ICM can improve the mobility, safety and security, and efficient use of capacity for transit modes and services. ICM strategies can also improve the quality of transit services, including the integration of transit modes with the overall transportation system in the corridor. With the availability and integration of data sources between transit stakeholders and DOTs, the following examples of ICM strategies with transit-specific benefits may become feasible:

- **Customer Trip-Planning and Wayfinding** – Tools and information displays can be used to inform travelers about travel choices, such as bus routes or rail stations in the corridor that can serve commuters. Trip-planning tools, most notably Google Transit, are widely used by transit riders to better understand transit options and schedules. For example, the San Diego ICM demonstration is providing en route and pre-trip traveler information and enhanced transit network information through a new 511 smartphone app for trip decision making. – *Potential benefits toward travel time reliability objectives.*
- **Real-Time Arrival and Status Information** – Many transit systems already use global positioning system (GPS)-based vehicle location systems to provide real-time train and bus information to inform customers of expected arrival time. Integrating bus location information with real-time traffic conditions (such as speeds) can improve the estimates of bus arrival times. – *Potential benefits toward travel time reliability objectives.*

- **Transit Access and Intermodal Transfers** – Information systems can improve the ability of riders to make intermodal transfers. For example, space availability at park-and-ride lots and transit stations can be broadcast along the corridor to help travelers select the best location to park. – *Potential benefits toward system efficiency and accessibility objectives.*
- **Incident/Operations Management** – Many regions have deployed procedures and communication systems to enable transit operators to receive real-time information on traffic congestion or disruptions, enabling operators to reroute buses around incidents. – *Potential benefits toward travel time reliability, system efficiency and safety objectives.*
- **Transit Signal Priority (TSP)** – In many corridors, traffic signal systems are being used to grant buses priority at intersections, through red truncation or extended green phases so as to allow buses to reduce intersection delay. Priority can be granted unconditionally to buses or can be conditional so that buses receive more green time when they are running behind schedule. TSP can also be used along with other roadway priority approaches such as queue jumps and bus lanes. – *Potential benefits toward travel time reliability and system efficiency objectives.*
- **Integrated Fare Payment** – Integrating payment media so that travelers can pay for parking and transit with the same contactless smart card can promote more seamless transfers. – *Potential benefits toward system efficiency objectives.*

Incident Response Stakeholders

ICM can improve the safety and security, mobility, and efficient use of capacity for incident response and emergency services. With the availability and integration of data sources between incident response stakeholders and DOTs, the following examples of ICM strategies with incident response-specific benefits may become feasible:

- **Local Agency Coordination** – A common challenge associated with major incident response situations is quickly and effectively coordinating with local jurisdictions and agencies to address evolving conditions that require immediate attention (e.g., deactivating live electrical wires, alerting rail agencies of obstructions/conditions that could impact their operations, and issuing evacuations). ICM can improve the process for identifying and communicating with the appropriate points of contact at each agency in various situations, as well as developing a predetermined set of procedures to be followed by each agency in a given situation as agreed on by all parties in advance. – *Potential benefits toward prompt, reliable, interoperable communication objectives.*
- **Coordinated Detour Routing** – With an ICM program, a set of approved detour routes for general traffic and for restricted vehicles (e.g., freight) can be determined in advance, along with the criteria and procedures for activating those routes. Doing so allows incident responders to quickly evaluate whether a detour route is warranted and to efficiently activate suitable detour routes as needed. With appropriate ICM detour route procedures, incident responders can be confident that detour routes can handle the diverted traffic. – *Potential benefits toward responder safety; safe, quick incident clearance; and prompt, reliable, interoperable communication objectives.*
- **Incident Confirmation** – A common challenge associated with incident response is confirming the location and details of an incident, so that suitable responders may be promptly dispatched to the proper location. Integration between CAD systems, state and local agency CCTV systems, real-time traffic performance-monitoring systems, and available personnel in the field (e.g., transit operators and tow truck operators) provides emergency dispatchers with the resources to confirm the specifics of an incident efficiently, thereby reducing response time and contributing to faster clearance times, reduced traffic impacts, fewer secondary

incidents, and other positive outcomes. – *Potential benefits toward responder safety; safe, quick incident clearance; and prompt, reliable, interoperable communication objectives.*

- **Efficient Incident Responder Dispatching** – In an emergency, dispatchers must work quickly to identify the proper points of contact for local responders, including fire departments, medical service providers, and police departments. An ICM program can improve the framework, procedures, and guidance to dispatchers to facilitate prompt identification of the proper agencies and organizations with jurisdiction in a given location and subsequent contacting of those agencies for incident response purposes. – *Potential benefits toward prompt, reliable, interoperable communication objectives.*
- **Incident Management Situation Tracking** – As conditions evolve during a major incident, emergency responders must respond to unanticipated problems and situations quickly and reliably. Through the coordination and communication framework provided by ICM, dispatchers and DOTs can more efficiently coordinate for traffic control purposes, such as requests for hard closures of lanes, entrances, or exits. They can similarly request DOT maintenance support for immediate hazards, including damaged infrastructure or large-scale debris, or can use CCTV imagery to check roadway shoulders before approving requests for emergency vehicles to drive on them. – *Potential benefits toward responder safety; safe, quick incident clearance; and prompt, reliable, interoperable communication objectives.*

Non-Motorized Roadway Users

The needs of non-motorized roadway users are often neglected when vehicular congestion mitigation strategies are discussed. ICM strategies have the potential to increase situational awareness, safety, and comfort among the members of this stakeholder group. With the availability and integration of data sources between non-motorized roadway users and DOTs, the following examples of ICM strategies with bicyclists and pedestrian-specific benefits may become feasible:

- **Pedestrian and Bicyclist Detection at Signalized Intersections** – Pedestrians are often instructed to wait, even during green phases, at signalized intersections. Wait times are more costly to pedestrians and bicyclists (relative to vehicle occupants) because they are exposed to the elements. Signal timing plans can be designed to grant pedestrian green time more frequently, or video detection of non-motorized roadway users waiting in the crosswalk area can be used to inform signal timing plans. – *Potential benefits toward equity and safety objectives.*
- **Expansion of Park-and-Ride Lots** – Expansion of park-and-ride lots within the corridor includes adding capacity to exiting lots, increasing the number of lots, and improving their ingress and egress to the freeways, adjacent transit stations, and local communities. These lots have significant potential to attract pedestrian and bicycle users who will board transit or carpools. Planning for these users could include bicycle paths, pedestrian trails, bike lockers, and other amenities that ensure that users make the most of these non-automobile modes, thus preserving space for automobile passengers who cannot access the lots on foot or bicycle. – *Potential benefits toward accessibility and connectivity objectives.*
- **Pedestrian and Bicyclist Crowdsourced Data Apps** – Limited by the technology to accurately detect and count bicyclists and pedestrians the way vehicle volumes are obtained, crowdsourced data may be an option for collecting this type of real-time and historical data. Most non-motorized roadway users are equipped with connected mobile devices. By designing a user-friendly app that collects their volumes, origins, and destinations, alternate routes for vehicles can be designed to include minimal conflict points with popular non-motorized roadway user routes. ICM teams may integrate bicyclist and pedestrian data in the same systems already being used to share and analyze vehicle data. – *Potential benefits toward safety objectives.*

- **Pedestrian and Bicyclist-Specific Traveler Information Dissemination** – Currently, traveler information disseminated through 511 systems and dynamic message signs are rarely relevant to non-motorized roadway users. Pedestrian and bicyclist-specific traveler information (e.g., impacts to non-motorized roadway users during incidents, vehicle volumes and speeds on arterials, intersection delays, high-frequency crash locations, impacts of ICM trip diversion on crash risk levels, quality of street lighting and sidewalks, etc.) may be more effectively communicated via real-time mobile alerts or pedestrian and bicyclist-specific trip planners. – *Potential benefits toward **safety** objectives.*

How Will This Stakeholder Group Be Involved in ICM Response Plans?

One of the key objectives of ICM is to optimize the use of existing system capacity during periods of non-recurring congestion. FHWA estimates non-recurring congestion to be responsible for 36% of congestion in large urban areas, 75% in small urban areas, and 95% in rural areas. ICM strategies are designed to promote responses appropriate to a specific incident, balancing the needs of first responders, persons involved in the incident, and the traveling public. Freeway incidents that involve lane closures and relatively long clearance times (e.g., due to injuries, fatalities, or hazardous cargo spills) may require diversion of traffic to frontage roads, arterials, or parallel transit services. Successful implementation requires several elements: understanding of current and anticipated traffic conditions, the ability to optimize capacity of all facilities involved (e.g., through arterial signal timing or reduction in transit service headways), and good coordination and communication among different stakeholders. Preplanning of these scenarios, including capacity and operational analysis of corridor facilities, communications protocols, and clearly defined responsibilities, is likely to enhance success.

Examples of delegated roles and responsibilities for each non-traditional stakeholder group are presented here for the six representative operational scenarios³⁵ listed. The first scenario is useful for recurring congestion conditions, while the other scenarios focus on addressing different types of incidents and planned events that can lead to non-recurring congestion. These examples can be used by agencies as a starting point for developing more specific response plans (e.g., location, duration, time of day, severity level, area of impact, etc.). The ITS backbone of all operational scenarios is an ICMS, which ideally contains a DSS component. The effectiveness of the DSS in these time-sensitive scenarios is dependent on data integration from separate agency systems and automated analysis and information dissemination.

- **Daily operations (Table 16)** – The agencies with operational jurisdiction over the ICM corridor (e.g., State DOT, regional MPOs, and/or local DOTs) should take the lead in this scenario because they are in charge of monitoring freeway and arterial traffic flow, operating freeway and arterial field devices, and coordinating Freeway Service Patrol services.
- **Freeway incident (Table 17)** – The State DOT or regional MPO with jurisdiction over the freeway should take the lead in this scenario because they are likely to be the first to identify any unusual activity through their incident detection systems.
- **Arterial incident (Table 18)** – The local DOT with jurisdiction over the arterial should take the lead in this scenario because they are likely to be the first to identify any unusual activity through their incident detection systems.

³⁵ List of representative operational scenarios was based on the following report: Research and Innovative Technology Administration, Concept of Operations for the I-15 Corridor in San Diego, California. FHWA-JPO-08-009, March 2008. Available at: https://ntl.bts.gov/lib/30000/30300/30311/14395_files/14395.pdf

Table 16. Daily operations scenario.

General Description	Recurrent congestion that occurs during the same peak periods every day when traffic demand exceeds roadway capacity. No incidents (roadway, transit, arterials, weather, etc.) impact traffic flow.	
Operational Objectives	<ul style="list-style-type: none"> • Decrease travel time • Increase person throughput 	<ul style="list-style-type: none"> • Reduce delay • Increase speeds
ICM Strategies to Consider	<ul style="list-style-type: none"> • Freeway Service Patrolling • Dynamic ramp metering • Dynamic HOV lanes • High-occupancy toll (HOT) lanes • Dynamic reversible lanes/Dynamic lane management 	<ul style="list-style-type: none"> • Hard shoulder running • Transit Signal Priority • Bus Rapid Transit (BRT) lane management • Dynamic traveler information (DMSs, 511 systems, mobile app alerts) • Incentives for modal switch or off-peak travel
Agency/Entity	Roles and Responsibilities	
Regional MPOs and Local DOTs (Lead Agency)	<ul style="list-style-type: none"> • Monitor freeway and arterial traffic flow and other performance metrics • Operate freeway and arterial field devices (e.g., adjust ramp metering rates, HOT lane pricing, reconfigure lane directions, etc.) 	<ul style="list-style-type: none"> • Coordinate corridor operations • Provide and coordinate Freeway Service Patrol services
Freight	<ul style="list-style-type: none"> • Utilize dynamic traveler information sources and set up audible alerts for in-vehicle notifications 	<ul style="list-style-type: none"> • Check traffic congestion levels before planned departure and delay travel until off-peak period if possible
Transit	<ul style="list-style-type: none"> • Monitor transit vehicle locations, capacity levels and schedule adherence • Notify waiting passengers of the change in pick-up locations if using alternate route 	<ul style="list-style-type: none"> • Adjust transit service if necessary (e.g., release additional transit vehicles, route transit vehicle around congestion to maintain schedule adherence)
Incident Responders	<ul style="list-style-type: none"> • Receive incident notification calls and notify/dispatch necessary incident responders 	<ul style="list-style-type: none"> • Incident responder communicates dispatch status to ICM team
Non-Motorized Roadway Users	<ul style="list-style-type: none"> • Utilize dynamic traveler information sources and set up alerts for high crash risk locations 	<ul style="list-style-type: none"> • Avoid travel on major arterials with high levels of vehicular traffic

Table 17. Freeway incident operational scenario.

General Description	Major or minor incident affects traffic flow on at least one freeway lane. Incident potentially involves fatalities, injuries, lane closures, law enforcement actions, or hazardous materials.	
Operational Objectives	<ul style="list-style-type: none"> • Increase responder safety • Reduce secondary crashes • Decrease incident clearance time 	<ul style="list-style-type: none"> • Reduce delay • Maintain travel time reliability
ICM Strategies to Consider	<ul style="list-style-type: none"> • Common incident management system (combination of incident detection systems and incident response plans) • Emergency vehicle signal preemption • Queue warning • Variable speed limits (VSL) • Dynamic HOV lanes 	<ul style="list-style-type: none"> • Hard shoulder running • Dynamic traveler information (DMSs, 511 systems, mobile app alerts) • Dynamic routing around active incidents via actionable traveler information (e.g., travel times on alternate routes or modes) • Ramp meter and arterial traffic signal coordination
Agency/Entity	Roles and Responsibilities	
State and Local DOTs (Lead Agency: State DOT)	<ul style="list-style-type: none"> • Monitor incident detection systems (e.g., CCTVs, ATMSs) for unusual activity • Verify incident details and alert Highway Patrol • Dispatch traffic management team to provide traffic control around the primary incident and reduce chance of secondary incidents 	<ul style="list-style-type: none"> • Trigger DMS and 511 system updates to alert the traveling public of incident details and estimated clearance time (local jurisdictions may need to update their own DMSs) • Initiate response plan actions (e.g., signal timing plan changes, queue detection, variable speed limits, adjust lane restrictions, etc.)
Freight	<ul style="list-style-type: none"> • Avoid diverting trucks off the freeway unless nearby arterial has been permitted for freight travel • Reroute trucks to other freeways if alternate routes are available 	<ul style="list-style-type: none"> • Delay truck departure times until incident is cleared • Reschedule pick-ups or deliveries as needed, based on estimated delays
Transit	<ul style="list-style-type: none"> • Adjust transit service to avoid incident location • Provide additional service to travelers switching modes 	<ul style="list-style-type: none"> • Notify waiting passengers of the change in pick-up locations if using alternate route
Incident Responders	<ul style="list-style-type: none"> • Utilize dynamic traveler information sources to aid Highway Patrol in reaching the scene of the incident quickly and safely 	<ul style="list-style-type: none"> • Confirm incident details once on scene, initiate requests for the necessary incident responders (e.g., towing company, fire department, coroner's office, HAZMAT team, etc.), and estimate clearance time
Non-Motorized Roadway Users	<ul style="list-style-type: none"> • Utilize dynamic traveler information sources and set up alerts for high crash risk locations 	<ul style="list-style-type: none"> • Avoid travel on major arterials with high levels of vehicular traffic

Table 18. Arterial incident operational scenario.

General Description	Major or minor incident affects traffic flow on at least one arterial lane. Incident potentially involves fatalities, injuries, lane closures, law enforcement actions, or hazardous materials.	
Operational Objectives	<ul style="list-style-type: none"> • Increase responder safety • Reduce secondary crashes • Decrease incident clearance time 	<ul style="list-style-type: none"> • Reduce delay • Maintain travel time reliability
ICM Strategies to Consider	<ul style="list-style-type: none"> • Common incident management system (combination of incident detection systems and incident response plans) • Queue warning • Corridor signal coordination/Adaptive signal coordination • Freeway-arterial traffic coordination 	<ul style="list-style-type: none"> • Emergency vehicle signal preemption • Pedestrian countdown signals at intersections • Dynamic traveler information (DMSs, 511 systems, mobile app alerts) • Dynamic routing around active incidents via actionable traveler information (e.g., travel times on alternate routes or modes)
Agency/Entity	Roles and Responsibilities	
Regional MPOs and Local DOTs (Lead Agency: Local DOT)	<ul style="list-style-type: none"> • Local jurisdiction TMC operator receives automatic alert from common incident management system • Monitor incident detection systems (e.g., CCTVs, ATMSs) for activity that may further impact the arterial incident (e.g., nearby freeway incident) • Dispatch traffic management team to provide traffic control around the primary incident and reduce chance of secondary incidents 	<ul style="list-style-type: none"> • Monitor freeway and arterial congestion levels on shared ATMS • Trigger DMS and 511 system updates to alert the traveling public of incident details and estimated clearance time (local jurisdictions may need to update their own DMSs) • Initiate response plan actions (e.g., lane closures, ramp meter and/or signal timing plan changes, setting up portable DMSs for queue detection, etc.)
Freight	<ul style="list-style-type: none"> • Reroute trucks to other freight-permitted arterials if possible • Delay truck departure times until incident is cleared 	<ul style="list-style-type: none"> • Reschedule pick-ups or deliveries as needed, based on estimated delays
Transit	<ul style="list-style-type: none"> • Adjust transit service to avoid incident location • Notify waiting passengers of the change in pick-up locations if using alternate route 	<ul style="list-style-type: none"> • Provide additional service to travelers switching modes
Incident Responders	<ul style="list-style-type: none"> • Local police department is alerted to possible arterial incident via automated incident detection system, TMC CCTV feeds, transit operators, or 911 reports • Police department dispatcher uses dynamic traveler information to reach the scene of the incident quickly and safely 	<ul style="list-style-type: none"> • Police department confirms incident details once on scene, requests the necessary incident responders (e.g., towing company, fire department, coroner's office, HAZMAT team, etc.), and estimates clearance time • Coordinate with MPOs and local jurisdiction to close roads, freeway on-ramps, off-ramps if necessary
Non-Motorized Roadway Users	<ul style="list-style-type: none"> • Utilize dynamic traveler information sources and set up alerts for high crash risk locations 	<ul style="list-style-type: none"> • Avoid travel on major arterials with high levels of vehicular traffic

- **Transit incident (Table 19)** – The transit agency should take the lead in this scenario because the onboard transit operator is likely to be affected by the incident firsthand and can report the incident immediately to transit dispatchers.
- **Special event (Table 20)** – The regional MPO or local DOT should take the lead in this scenario because planned short-term or long-term events generally require advance coordination with these agencies who will implement the appropriate measures to handle temporary increases in traffic.
- **Disaster response (Table 21)** – Incident responders should take the lead in this scenario because 911 will be the first point of contact.

Take the following steps to use these tables:

1. When designing a response plan, refer to the appropriate table for a starting point example of that particular operational scenario.
2. Review the **ICM Strategies to Consider** to make sure that you have considered all options for achieving your **Operational Objectives**.
3. Review the suggested **Roles and Responsibilities** of each stakeholder group to ensure that your response plan covers all bases.

How Can We Analyze the Expected Impacts of the Envisioned ICM System?

Once ICM strategies have been narrowed down and key performance measures have been identified, an analysis plan will need to be developed. As part of the FHWA Traffic Analysis Toolbox (Volume XIII), the Integrated Corridor Management Analysis, Modeling, and Simulation Guide³⁶ (updated in 2017) was designed to help corridor stakeholders implement the ICM AMS method successfully and effectively. **Appendix E, Analysis Methodology, Tools, and Plan** condenses the main points, namely, the value, approach, challenges, and resources required of each of the five worksteps included in the AMS Guide (refer to Figure 11). For more in-depth details on this method, please refer to FHWA's full report. A major component of the analysis plan is data collection, which can include input data for AMS, performance data for model calibration and validation, and data for ICM approaches and strategies.

The summary in **Appendix F, Data Needs Assessment** of the *AMS Data Collection Plan for the I-15 Pioneer Corridor*, outlines the various tasks associated with identifying the data that need to be collected for AMS tools and strategies in order to support benefit-cost assessment for the successful implementation of ICM.

What Resources Are Available from Successful ICM Projects?

The ICM Initiative, which the USDOT launched in 2006, has supported two demonstration sites (San Diego I-15 and Dallas U.S. 75) from the initial planning phases through implementation. They are conducting post-deployment analysis to document the main lessons learned for other agencies looking to pursue ICM. In 2015, USDOT's FHWA awarded \$2.6 million in grants to 13 highly congested urban areas for pre-implementation ICM activities, as shown in Figure 12.

³⁶ FHWA, *Traffic Analysis Toolbox Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide*, FHWA-JPO-16-397, February 2017.

Table 19. Transit incident operational scenario.

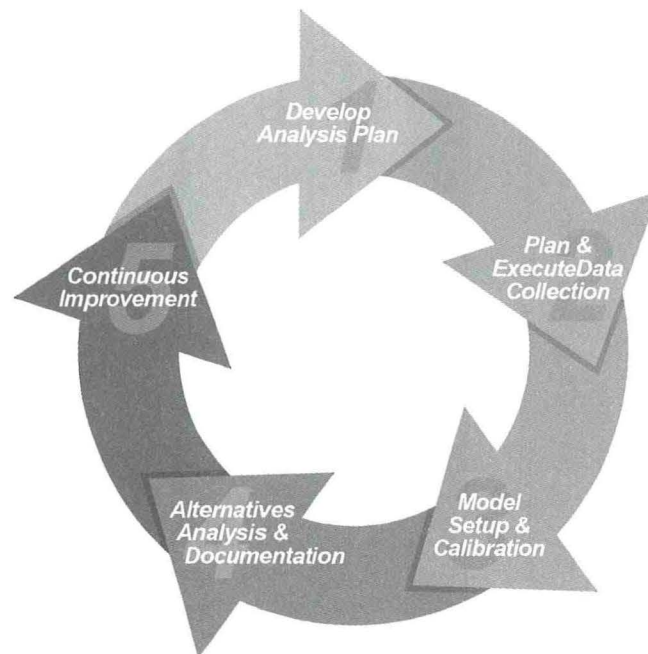
General Description	Major or minor incident affects transit vehicle. Incident potentially involves vehicle mechanical failures, passenger medical issues, crash with a motor vehicle, etc.	
Operational Objectives	<ul style="list-style-type: none"> • Establish passenger safety • Increase responder safety • Reduce secondary crashes 	<ul style="list-style-type: none"> • Decrease incident clearance time • Reduce delay • Maintain travel time reliability
ICM Strategies to Consider	<ul style="list-style-type: none"> • Common incident management system (combination of incident detection systems and incident response plans) • Emergency vehicle signal preemption • Automatic vehicle location (AVL) • Computer-aided dispatch (CAD) • Corridor signal coordination/Adaptive signal coordination 	<ul style="list-style-type: none"> • Freeway-arterial traffic coordination • Pedestrian countdown signals at intersections • Queue warning • Dynamic traveler information (DMSs, 511 systems, mobile app alerts) • Dynamic routing around active incidents via actionable traveler information (e.g., travel times on alternate routes or modes)
Agency/Entity	Roles and Responsibilities	
Regional MPOs and Local DOTs	<ul style="list-style-type: none"> • Reported incident is automatically disseminated to ICM team • Trigger DMS and 511 system updates to alert the traveling public of incident details and estimated clearance time (local jurisdictions may need to update their own DMSs) • Monitor incident detection systems (e.g., CCTVs, ATMSs) for activity that may further impact the transit incident (e.g., nearby arterial incident) 	<ul style="list-style-type: none"> • Dispatch traffic management team to provide traffic control around the primary incident and reduce chance of secondary incidents • Monitor freeway and arterial congestion levels on shared ATMS • Initiate response plan actions (e.g., lane closures, ramp meter and/or signal timing plan changes, setting up portable DMSs for queue detection, etc.)
Freight	<ul style="list-style-type: none"> • Reroute trucks to other freight-permitted arterials if possible • Delay truck departure times until incident is cleared 	<ul style="list-style-type: none"> • Reschedule pick-ups or deliveries as needed, based on estimated delays
Transit (Lead Agency)	<ul style="list-style-type: none"> • On-board transit operator reports incident or activates panic button • Identify on-board passengers in need of aid 	<ul style="list-style-type: none"> • Dispatch vehicle maintenance or additional transit vehicle to transport on-board passengers
Incident Responders	<ul style="list-style-type: none"> • Local police department is alerted to possible arterial incident via automated incident detection system, TMC CCTV feeds, transit operators, or 911 reports • Police department dispatcher uses dynamic traveler information to reach the scene of the incident quickly and safely 	<ul style="list-style-type: none"> • Police department confirms incident details once on scene, requests the necessary incident responders (e.g., towing company, fire department, coroner's office, HAZMAT team, etc.), and estimates clearance time • Coordinate with MPOs and local jurisdiction to close roads, freeway on-ramps, off-ramps if necessary
Non-Motorized Roadway Users	<ul style="list-style-type: none"> • Utilize dynamic traveler information sources and set up alerts for high crash risk locations 	<ul style="list-style-type: none"> • Avoid travel on major arterials with high levels of vehicular traffic

Table 20. Special planned event operational scenario.

General Description	Planned short-term or long-term event that is expected to result in increased traffic levels and requires heightened coordination between transportation and public safety operations. Special events may involve sporting events, concerts, major conventions, visiting dignitaries, etc.	
Operational Objectives	<ul style="list-style-type: none"> • Increase security surveillance • Increase person throughput 	<ul style="list-style-type: none"> • Reduce delays • Reduce emissions and fuel consumption
ICM Strategies to Consider	<ul style="list-style-type: none"> • Dynamic reversible lanes/Dynamic lane management • Transit signal priority • Bus Rapid Transit lane management • Pedestrian countdown signals at intersections • Queue warning 	<ul style="list-style-type: none"> • Smart parking system • Corridor signal coordination/Adaptive signal coordination • Dynamic traveler information (DMSs – permanent or portable, 511 systems, mobile app alerts) • Dynamic routing via actionable traveler information especially for temporary road closures or restrictions
Agency/Entity	Roles and Responsibilities	
State and Local DOTs (Lead Agency)	<ul style="list-style-type: none"> • Issue public announcements, press releases, 511 system updates to inform the public of any planned road/ramp closures or restrictions • Implement and monitor road/ramp closures or restrictions • Set up portable message signs around event location • Monitor freeway and arterial traffic flow and other performance metrics 	<ul style="list-style-type: none"> • Operate freeway and arterial field devices (e.g., adjust signal timing plans, adjust lane restrictions, reconfigure lane directions, etc.) • Disseminate real-time parking information on traveler information sources • Provide additional security personnel for traffic control
Freight	<ul style="list-style-type: none"> • Reroute trucks to non-impacted alternate route 	<ul style="list-style-type: none"> • Reschedule pick-up or deliveries during non-event hours
Transit	<ul style="list-style-type: none"> • Monitor transit vehicle locations, capacity levels and schedule adherence • Coordinate schedules among service providers (e.g., provide temporary additional transit capacity and/or on-demand transit service for event attendees) 	<ul style="list-style-type: none"> • Disseminate new transit schedules and/or pick-up locations to traveling public if necessary
Incident Responders	<ul style="list-style-type: none"> • Coordinate with MPOs and local jurisdiction to close roads, freeway on-ramps, off-ramps if necessary 	<ul style="list-style-type: none"> • Provide additional security personnel for street patrol and traffic control
Non-Motorized Roadway Users	<ul style="list-style-type: none"> • Follow suggested route options 	<ul style="list-style-type: none"> • Utilize dynamic traveler information to avoid closed or restricted roads

Table 21. Disaster response operational scenario.

General Description	Large-scale incidents potentially resulting in long-term full freeway/arterial closures and evacuations. Incident potentially involves natural disasters or man-made incidents such as terrorist attacks.	
Operational Objectives	<ul style="list-style-type: none"> • Safety of the public, incident responders, transportation operations 	
ICM Strategies to Consider	<ul style="list-style-type: none"> • Common incident management system (combination of incident detection systems and incident response plans) • Emergency vehicle signal preemption • Transit signal priority • Bus Rapid Transit lane management • Ramp meter and arterial traffic signal coordination • Dynamic HOV lanes • Dynamic reversible lanes/Dynamic lane management • Dynamic traveler information (DMSs, 511 systems, mobile app alerts) 	
Agency/Entity	Roles and Responsibilities	
Regional MPOs and Local DOTs	<ul style="list-style-type: none"> • Implement and monitor road/ramp closures or restrictions • Issue public announcements, press releases and trigger DMS and 511 system updates to alert the traveling public of incident details, road closures, and other impacts • Deploy portable message signs at critical locations • Operate freeway and arterial field devices (e.g., adjust lane restrictions, reconfigure lane directions, adjust signal timing plans, etc.) • Monitor freeway and arterial traffic flow and other performance metrics 	
Freight	<ul style="list-style-type: none"> • Reroute trucks to non-impacted alternate routes • Reschedule pick-ups or deliveries as needed, based on severity of incident 	
Transit	<ul style="list-style-type: none"> • Coordinate schedules among service providers (e.g., provide short-term additional transit capacity and/or on-demand transit service for evacuees) • Disseminate new transit schedules and/or pick-up locations to traveling public if necessary 	
Incident Responders (Lead Agency)	<ul style="list-style-type: none"> • Receive incident notification via 911 report and dispatch necessary incident responders • Update incident details in common incident management system • Provide additional security personnel for traffic control, evacuation support services 	
Non-Motorized Roadway Users	<ul style="list-style-type: none"> • Utilize traveler information sources for travel instructions (e.g., stay indoors, evacuate to nearest safe facility, avoid closed/restricted roads, etc.) 	



Source: Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc., 2017

Figure 11. Integrated Corridor Management analysis, modeling, and simulation approach worksteps.



Source: <https://www.fhwa.dot.gov/pressroom/fhwa1504.cfm>.

Figure 12. Nationwide Integrated Corridor management activity as of August 2017.

FHWA and individual cities pursuing ICM have published multiple reports throughout the ICM initiative; these reports can be used as references to aid transportation professionals in implementing their own ICM projects. Here are several pertinent resources:

- **FHWA Office of Operations Corridor Traffic Management webpage**³⁷ – This is FHWA’s main page on ICM.
- **Office of the Assistant Secretary for Research and Technology Intelligent Transportation Systems Joint Program Office (ITS-JPO) Integrated Corridor Management Knowledgebase**³⁸ – This is ITS-JPO’s research archive of all ICM-related publications, organized by ICM lifecycle phase or system engineering process step.
- **Scoping and Conducting Data-Driven 21st Century Transportation System Analyses**³⁹ – This FHWA publication is a guide on the systematic integration of data and analytic resources into transportation systems management.
- **FHWA Office of Operations Traffic Analysis Tools Program**⁴⁰ – The Traffic Analysis Tools Program was formulated by FHWA in an attempt to strike a balance between efforts to develop new, improved tools in support of traffic operations analysis and efforts to facilitate the deployment and use of existing tools. FHWA has established two tracks under the Traffic Analysis Tools Program: the deployment track and the development track. *Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide* is among the documents relevant for ICM.
- **NCHRP 03-121 Guidebook Appendix G, Documentation for Integrated Corridor Management Deployments** – This appendix provides design details of real-world ICM systems of various scales, including the San Diego I-15 and Dallas U.S. 75 Demonstration Sites, as well as the smaller scale Kansas I-35 ICM project.

³⁷ <https://ops.fhwa.dot.gov/index.asp>.

³⁸ https://www.its.dot.gov/research_archives/icms/icm_lifecycle.htm.

³⁹ <https://ops.fhwa.dot.gov/publications/fhwahop16072/index.htm>.

⁴⁰ <https://ops.fhwa.dot.gov/trafficanalysistools/index.htm>.



CHAPTER 9

Initiate Formal Arrangements

Formalize institutional, organizational, and technical arrangements with stakeholders to ensure the long-term success of the ICM project.

How Do We Formalize This ICM Process So That We Can Ensure That Our Response Plans Operate Smoothly in the Long Term?

Managing a dynamic corridor effectively requires an equally dynamic management of arrangements among ICM system stakeholders. ICM solutions are often deployed in highly complex and dynamic transportation corridors. These complex transportation corridors have an equally complex set of stakeholders that include freight, transit, incident response, and non-traditional (pedestrian/bicyclist) stakeholders. Successful ICM deployments over time must recognize that just as the tangible corridor assets made of concrete, asphalt, steel, and silicon must be maintained and sometimes refreshed or replaced, the arrangements binding stakeholders together must also be maintained and sometimes refreshed or replaced. As user needs and technology change, how the ICM is conceptualized, defined, operated, and financed among stakeholders must change in response. The arrangements enabling the ICM system to function must also include mechanisms so these arrangements can be adapted over time. The documents describing the shared vision, roles, responsibilities, and tactical arrangements made among the ICM system stakeholders – the *institutional capital* of the ICM system – are arguably the most critical ICM assets to ensure long-term cohesion among stakeholders and long-term viability of the ICM deployment.

If an ICM system is deployed as a static build-and-forget solution, it may soon become ineffective, irrelevant, and eventually abandoned in favor of other more relevant solutions aligned with current issues and concerns. Technical, organizational, and institutional arrangements are bringing together ICM stakeholders to periodically reexamine corridor performance, emerging threats/issues, underlying changes in corridor traveler/user needs and demand patterns, ICM system capabilities, and the potential of emerging technologies. These periodic assessments should begin with challenging the previous purpose and nature of the ICM system; assess the capability of the ICM to meet performance goals and make plans to refine/replace unsatisfactory aspects of the ICM system.

Appendix H, Institutional, Organizational, and Technical Arrangements, provides a detailed examination of the arrangements among ICM stakeholders, including examples specifically targeting considerations of freight, transit, incident response, and pedestrian/bicyclist stakeholders. The arrangements are presented according to the following classification:

- **Institutional arrangements**, governing how ICM stakeholders determine and guide the strategic direction of the ICM deployment over time, including geographic boundaries, scopes of actions, financial plans, stakeholder engagement/retention, and institutional form.
- **Organizational or operational arrangements**, governing the roles, responsibilities, limitations, and tactical interactions among ICM system operators engaged in real-time day-to-day decision making within the corridor.
- **Technical arrangements**, governing the ownership and responsibility among stakeholders for the security, monitoring, maintenance, and enhancements of ICM system assets (both tangible and intangible).

What Types of Arrangements Are Suitable for Our ICM Project?

The second part of **Appendix H, Institutional, Organizational, and Technical Arrangements** provides a structured exercise for ICM stakeholders to assess the maturity of the existing ICM institutional capital and to identify the most likely technical, organizational, and institutional arrangements to either create or enhance.

This exercise can be useful for ICM deployments in a range of deployment maturity – from early to advanced deployments. Such an exercise is recommended when the ICM solution needs to be expanded to include new stakeholders (e.g., freight, transit, incident response, and non-motorized stakeholders).

Exercise Purpose – The purpose of the exercise is to collectively assess the maturity of current ICM institutional capital with respect to current or future needs and identify and prioritize the creation or updating of specific institutional, organizational, and technical arrangements.

Exercise Outcomes – The expected outcomes of the exercise are to:

1. Improve the level of engagement of all stakeholders in a shared ICM vision; and
2. Create a punch list of high-priority actions to be taken in strengthening arrangements among stakeholders.

When to Conduct This Exercise – This exercise (or something similar in intent) can be incorporated into a periodic (e.g., annual) meeting of ICM stakeholders. In many cases, it may be useful as a capstone exercise after a broader discussion of corridor performance, needs, and stakeholders. If this discussion has not been facilitated, then time must be added to the exercise to provide the context of corridor vision and key next steps that will shape what is needed in terms of institutional capital.

Who Should Participate – The exercise is intended for the individuals who are the champions of the corridor concept. These need not necessarily be drawn from the ranks of senior leadership among stakeholder organizations. At least one participant should attend for each of the major corridor stakeholder groups. That said, the exercise will be impractical for large groups. A practical maximum of 16–20 participants with a target size of 6–12 motivated stakeholders can be used as a rough guide to help size the exercise and determine who should participate.

Required Preparation and Materials – The exercise is designed to be conducted as an in-person, roundtable event. However, virtual participation by some (or even all) stakeholders can be supported, given that there is a method to collect and display information that all stakeholders can simultaneously view. A no-visual teleconference connection is not recommended for any participants. Practically, this means at a minimum a whiteboard for a purely in-person event. However, an arrangement where a computer desktop can be simultaneously viewed

(by both in-person attendees and virtual attendees) is likely to be the best solution. One individual should be assigned the role of exercise facilitator (and timekeeper) and another assigned the role of recorder/scribe for the exercise.

Table 22 is the ICM Capability Maturity Model for use in the exercise. To use this table, follow these steps:

1. Assess where the ICM project stands now along each dimension.
2. Assess where you want to be in a certain period of time (e.g., 5 years).
3. Start making plans for incremental improvements to achieve the desired maturity level.

As the Demands of Our ICM System Change Over Time, How Does Our Organizational Form Need to Adapt?

Below is a high-level summary of prototypical organizational frameworks among ICM system stakeholders spanning a range of more ad hoc and informal forms to more formal and systematic structures. Each of the individual frameworks is presented in additional detail in **Appendix I, Alternative Integrated Corridor Management Frameworks**. The maturity assessment described previously is re-used to examine the pros and cons of adapting to a new organizational form as the demands on the ICM system change over time.

Ad Hoc Coordination (early model, Levels 1–2)

In this early model (see Figure 13), there is no formal charter or ICM concept. However, there is corridor-level coordination that occurs informally among stakeholders because of the natural intersection of corridor issues, events, conditions, and aspects that may have brought stakeholders together in the past. In some cases, staff in one organization may have worked previously in another organization, and personal relationships act as natural bridges among corridor stakeholders.

Roundtable of Champions (early model, Levels 1–3)

In this early model (see Figure 14), senior leaders gather to initiate or further develop an ICM concept. In this case, creating a charter for the corridor stakeholders and establishing goals may be an early agenda item. The *Roundtable of Champions* model can be characterized as relatively senior management in each organization creating a roundtable of similar individuals across the ICM stakeholder spectrum and inviting participation.

Peer-to-Peer Connection (early model, Levels 1–3)

In this early model (see Figure 15), technical and operations staff gather to solve specific corridor issues. In this case, this is a natural extension of the *Ad Hoc Coordination* model but advanced to a more mature state where trust relationships among multiple individuals have evolved into trust relationships among sub-elements of individual stakeholder organizations. These connections are encouraged, and possibly authorized, by the chain of command within each participating organization.

Coordinated Operations (intermediate model, Levels 3–4)

In this model (see Figure 16), stakeholders have formalized an agreement to coordinate activity, either in a playbook or a set of flexible rules. In many cases, the key difference between the early models and this intermediate model is a more mature set of institutional capital.

Table 22. Application of the Integrated Corridor Management capability maturity model.

		Level 1 Silo	Level 2 Centralized	Level 3 Partially Integrated	Level 4 Multimodal Integrated	Level 5 Multimodal Optimized
<i>Institutional Integration</i>	Inter-Agency Cooperation	Agencies do not coordinate their operations	Some agencies share data but operate their networks independently	Agencies share data, and some cooperative responses are done	Agencies share data, and implement multimodal incident response plans	Operations are centralized for the corridor, with personnel operating the corridor cooperatively
	Funding	Single agency	MPO tracks funding	Coordinated funding through MPO	Cooperatively fund deployment projects	Cooperatively fund deployment and operations and maintenance projects
<i>Technical Integration</i>	Traveler Information	Static information on corridor travel modes	Static trip planning with limited real-time alerts	Multimodal trip planning and account-based alerts	Location-based, on-journey multimodal information	Location-based, multimodal proactive routing
	Data Fusion	Limited or Manual	Near real-time data for multiple modes	Integrated multimodal data (one-way)	Integrated multimodal data (two-way)	Multi-source multimodal data integrated and fused for operations
<i>Operational Integration</i>	Performance Measures	Some ad hoc performance measure based on historical data	Periodic performance measures based on historical data	High-level performance measures using real-time data	Detailed performance measures in real time for one or more modes	Multimodal performance measures in real time
	Decision Support System	Manual coordination of response	Pre-agreed incident response plans	Tool selection of pre-agreed plans	Model-based selection of pre-agreed plans	Model-based creation of incident response plans

Source: National Cooperative Highway Research Program Project 20-68A, Scan 12-02.

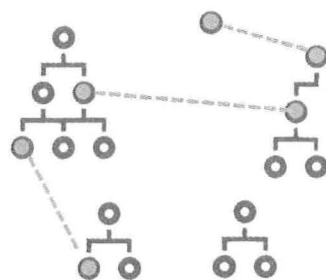


Figure 13. Ad hoc coordination model.

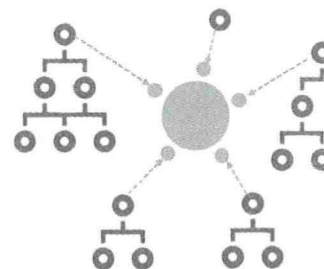


Figure 14. Roundtable of champions model.

Specifically, this framework requires more detailed operational and technical arrangements that spell out the specific roles and responsibilities and sequence of actions taken in response to observed conditions in the corridor. Broadly, this framework reflects the organizational form of the USDOT ICM deployment sites after deployment.

Integrated Consortium (advanced model, Levels 4–5)

In this advanced model (see Figure 17), corridor management roles and practices are well defined and more formal corridor-specific organizational structures are required to improve efficiency and accountability. A new corridor-level organization is formed to carry out these roles and practices, staffed by individuals drawn from stakeholder organizations. Note that there are no current examples of the *Integrated Consortium* framework currently deployed for the purposes of ICM. This model may be of interest for consideration but cannot be described as a proven ICM organizational model.

Third-Party Operator (advanced model, Levels 4–5)

In this advanced model (see Figure 18), corridor management roles and practices are well defined and more formal corridor-specific organizational structures are so well defined that a separate organization is hired or formed to carry out these roles and practices. No current examples of the *Third-Party Operator* framework are deployed for the purposes of ICM. This model may be of interest for consideration but cannot be described as a proven ICM organizational model.

These frameworks can be used to assess if a change in organizational form may be required to meet changing corridor needs – which needs may be identified in periodic strategic assessment

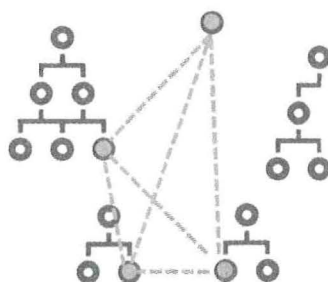


Figure 15. Peer-to-peer connection model.

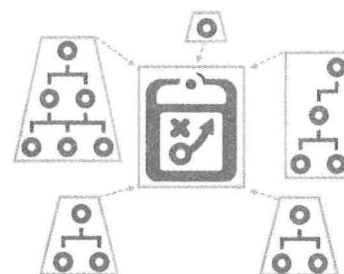


Figure 16. Coordinated operations model.

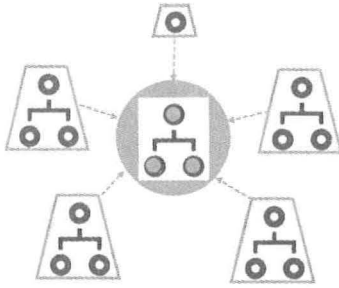


Figure 17. Integrated consortium model.

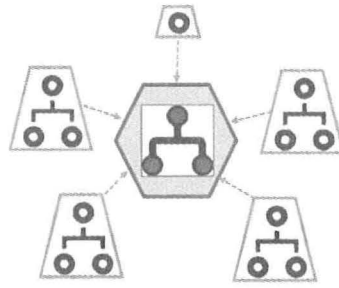


Figure 18. Third-party operator model.

sessions modifying key institutional arrangements. Key questions stakeholders should periodically consider in joint session are as follows:

- Is the corridor meeting or exceeding performance goals?
- Are there new issues/stakeholders?
- Are the geographic boundaries of the corridor practical and relevant?
- Which days in the previous year were the most problematic? Most successful? What are the attributes of these successes and failures?

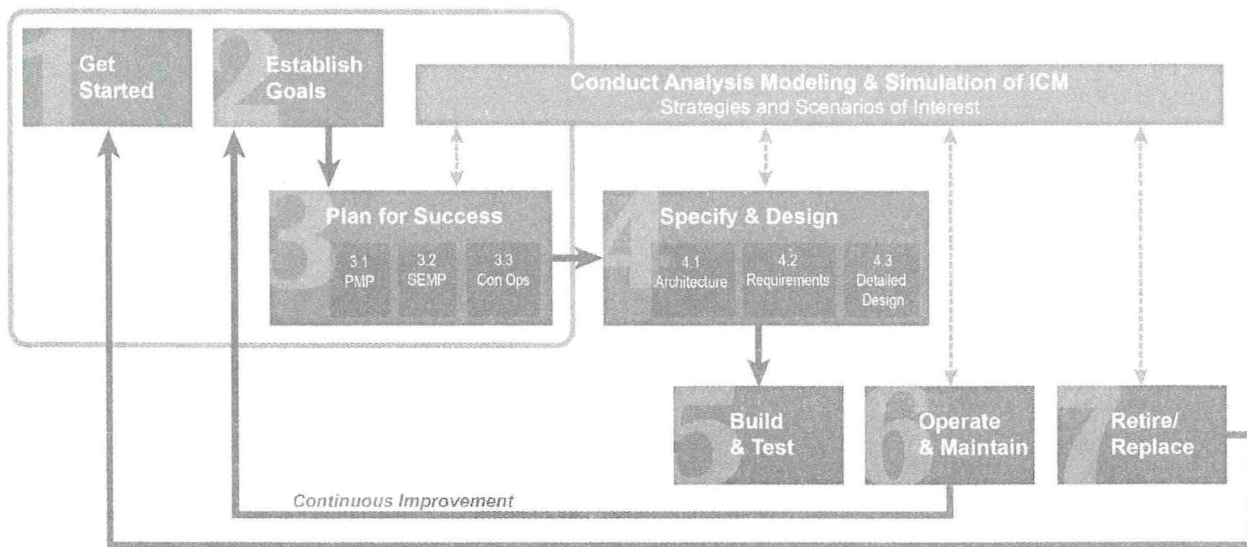


CHAPTER 10

Next Steps for Integrated Corridor Management Implementation

In terms of FHWA's ICM implementation process phases, the focus of this Guidebook's ICM Planning Framework is on **Steps 1, 2, and 3**. These steps involve engaging new partners in order to develop the most effective ICM strategy portfolio. Upon completing the eight steps in the ICM Planning Framework, transportation agencies will then need to do a detailed design of the ICMS, build and test the system, operate and maintain the accepted ICMS, and eventually retire or replace ICMS elements that have become obsolete. These steps are outlined below and in Figure 19:

1. **Get Started.** This phase includes the activities conducted to identify and coordinate the participants and information necessary to plan an ICM project: foster champions and organize stakeholders; coordinate with planning process; interface with the regional ITS architecture; and develop and approve project charter.
2. **Establish Goals.** This phase includes the activities necessary for the stakeholders to gain an understanding of ICM and to initiate the planning for an ICM project: explore the ICM concept; develop goals, measurable objectives, and data collection needs; analyze system problems and identify system/user needs; conduct feasibility assessment; and identify development support resources.
3. **Plan for Success.** This phase includes the activities for organizing the management and technical programming approach to ICM in a region and implementing an ICMS. This phase is divided into the three main documents produced during this phase of the project:
 - 3.1. Project Management Plan (PMP) – Assess project management activities; determine roles and responsibilities; initiate procurement discussions; prepare PMP and supporting plans (as needed).
 - 3.2. Systems Engineering Management Plan (SEMP) – Assess project management activities and technical tasks; transition critical technologies; define needed systems engineering processes and resources; make procurement decisions and specify integration activities; prepare SEM.
 - 3.3. Concept of Operations (ConOps) – Define/refine project vision, goals and objectives; explore project concepts; develop operational scenarios; develop and document project ConOps; define system boundaries.
4. **Specify & Design.** This phase includes the activities for specifying and designing an ICMS. This phase is divided into the three main documents produced during this phase of the project:
 - 4.1. System Architecture – Develop, deconstruct, and evaluate project architecture alternatives; identify and evaluate internal and external interfaces; evaluate industry standards and identify standards gaps; select and document the high-level design; perform preliminary design review; conduct a traceability review.



Source: Office of the Assistant Secretary for Research and Technology, ITS JPO

Figure 19. Integrated Corridor Management implementation process phases.

- 4.2. System Requirements – Develop requirements; write and document requirements; review for completeness; analyze, refine, and decompose requirements; manage requirements; perform technical reviews; perform preliminary design review.
- 4.3. System Design (Detailed Design) – Perform detailed design; evaluate commercial off-the-shelf products and applications; perform technical reviews; perform critical design review; perform tradeoff studies; ensure traceability.
5. **Build & Test.** After the critical design review has been completed and the detailed design has been approved, system development and implementation can begin. Key activities in this phase include performing component development; purchasing commercial off-the-shelf products and applications; integrating system components, products and applications; conducting a traceability review; developing operations, maintenance, and training manuals and plans; and conducting training.
6. **Operate & Maintain.** Once the ICMS has been accepted, stakeholders will take over the responsibility of operating and maintaining the system. Because the system will serve so many corridor operators for many different purposes, decisions need to be made about the roles and responsibilities for system operations and maintenance (O&M). Key activities in this phase include planning O&M, collecting O&M information, performing O&M, monitoring and assessing system performance, identifying changes to O&M procedures, updating O&M procedures, and validating the system.
7. **Retire/Replace.** Eventually the ICMS may become obsolete or require a major overhaul, replacing some or all of the original system. Stakeholders will need to have a plan in place to accommodate these types of changes when they occur. A system retirement or replacement plan should be included in the ICMS SEMP. Key activities in this phase include assessing system retirement/replacement, analyzing system performance, assessing alternative ICM and/or ICMS options, assessing system disposal costs, and assessing system replacement costs.



Appendices

Characteristics of Recurrent and Non-Recurrent Congestion

This appendix provides a data-driven foundation to understand and characterize the range of operational conditions that drive congestion patterns, corridor performance, and integrated management response.

- First, the guidance establishes the motivation for Integrated Corridor Management (ICM) stakeholders to define operational conditions rigorously using observed data to help create a consensus view on patterns of corridor congestion.
- Second, the guidance discusses how the data needed to support this effort can be collected, analyzed, and visualized.
- Third, the guidance provides lessons-learned and proposed processes to create practical and data-driven ICM response plans that are created through stakeholder interaction using data-driven characterizations of operational conditions.

The goal is to provide the ICM stakeholders with the tools to right-size the chosen transportation management methods suited to the technical and institutional capabilities at hand—and set a course for improvement over time.

Characterizing and Visualizing Operational Conditions

This appendix provides a review of different methods for visualizing and communicating the severity, extent (temporal or spatial), nature, and/or characteristics of congestion, such as through color-coded network diagrams, GIS maps, speed contour plots, travel time reliability charts, vehicle trajectory plots (i.e., time-space vehicle plots), cumulative count curves, and other methods.

An operational conditions analysis ingests several months of contemporaneous, time-dynamic travel time, bottleneck throughput, weather, incident, and travel demand data to create mutually exclusive and exhaustive set of similar conditions—and their frequency of occurrence. For example, an analysis of a corridor identified 30 distinct operational conditions, depicted in FIGURE A.1. The figure organizes the 30 conditions spatially based on increasing travel demand (along the x-axis) and disruptions to roadway supply (along the y-axis). Each condition is a collection

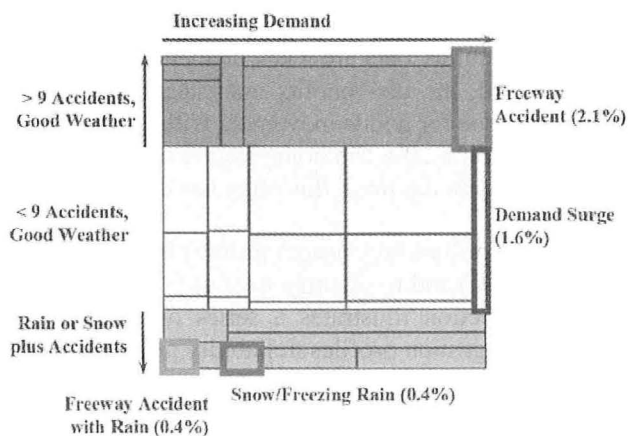


FIGURE A.1. Visualizing operational conditions in the Seattle I-5 Corridor (Federal Highway Administration).

of four or more actual days, and the total size of the box representing the condition reflects its frequency of occurrence.

In 2017, FHWA released a key document related to the systematic identification of operational conditions—developed and authored by Cambridge Systematics Team members. This document is a guide on the systematic integration of data and analytic resources into transportation systems management, *Scoping and Conducting Data-Driven 21st Century Transportation System Analyses*. This guidebook provides a wealth of material to reference and draw upon for the ICM community, and this appendix in the NCHRP 03-121 Guidebook draws heavily from the 21st Century Guide. Further, the basic concepts of the ICM AMS Guide are highly consistent and complementary with these materials. The goal of the ICM-specific guidance is not to parrot these materials, but to put the statistical methods and data management processes detailed in each FHWA guidebook into context for the ICM stakeholder.

ICM focuses on various multimodal travel scenarios under varying operational conditions, in particular both recurrent and non-recurrent traffic congestion. A corridor's non-recurrent congestion scenarios entail combinations of demand increases and capacity decreases. The overall premise is that key ICM impacts may be lost if only “normal” travel conditions are considered. The ICM scenarios take into account both average- and high-travel demand within the corridor, with and without incidents. The relative frequency of non-recurrent operational conditions (i.e., incidents or other significant non-recurrent operational conditions that affect corridor performance such as work zones, special events, weather, etc.) is also important to estimate (based on archived traffic conditions) in this process. While ICM is designed to address both recurrent and non-recurrent events, the post-deployment evaluation of the two demonstration sites (Dallas and San Diego) focused solely on incident- or congestion-related events. The potential ICM deployment-related alternatives were identified using cluster analysis that grouped together incidents or congestion events that occurred under operational conditions (e.g., time of day, direction of traffic, length of time until the incident was cleared, etc.) which were more similar to each other, than to those in other groups (clusters). These clusters were then prioritized based on total delay impact.

Data and tools can be brought together to provide increasingly robust and quantitative measures of system performance. Some useful measures of system products over some time (e.g., a peak period, or a day, or a month) may include reliably completed trips and total value of goods delivered. These may be hard to measure directly. However, using time-variant travel time data and supporting estimates of ridership and volume data, travel reliability analysis can be conducted that is a key first step in the measurement of system product. Reliability data are a key element in characterizing trip-making since, if a trip takes much longer than expected, the dis-benefits associated with disrupting travel plans outweigh the benefits. This is particularly true for goods movement within a supply chain, but the same basic principles hold for person-trips. For example, if a trip home from work takes so much longer than expected that changes to childcare arrangements are required, this often has direct and measureable financial consequences.

The purpose of building system profiles is to characterize system performance (i.e., the system is getting better or worse) and to identify what are missing in the profile so the profile can be improved in the long term. This section illustrates a series of example system profiles (including their key components), including congestion profiles, reliability profiles, and safety profiles.

Congestion Profile

Time-variant congestion measures may contain travel time, vehicle delay, bottleneck throughput, queue length, vehicle stops and other attributes depending on the nature of the problem and the system features. For example, to create a freeway corridor congestion profile, travel time and bottleneck throughput may be selected as performance measures; to analyze an intersection performance, queue length and vehicle delay may be used throughout the study. FIGURE A.2 presents an example of congestion maps from Washington

Department of Transportation (WSDOT).¹ Using speed data, WSDOT has archived a system-wide congestion map on 10-minute intervals since January 2013. These maps can be used in sequence in a simple and intuitive way to identify problem/bottleneck locations as well as other changes within the system over time.

If local agencies are interested in exploring opportunities to divert freeway or arterial traffic to transit, they will engage in collaborative dialogue with the regional transit managers to understand possibilities for creating available transit capacity, including parking facilities, to accommodate the possible influx of demand under certain scenarios. FIGURE A.3 presents example comparisons of expected changes in delays in a transportation network that contains both freeway and arterial segments; such comparisons help stakeholders visually assess expected improvements and reductions in service in different parts of the network.

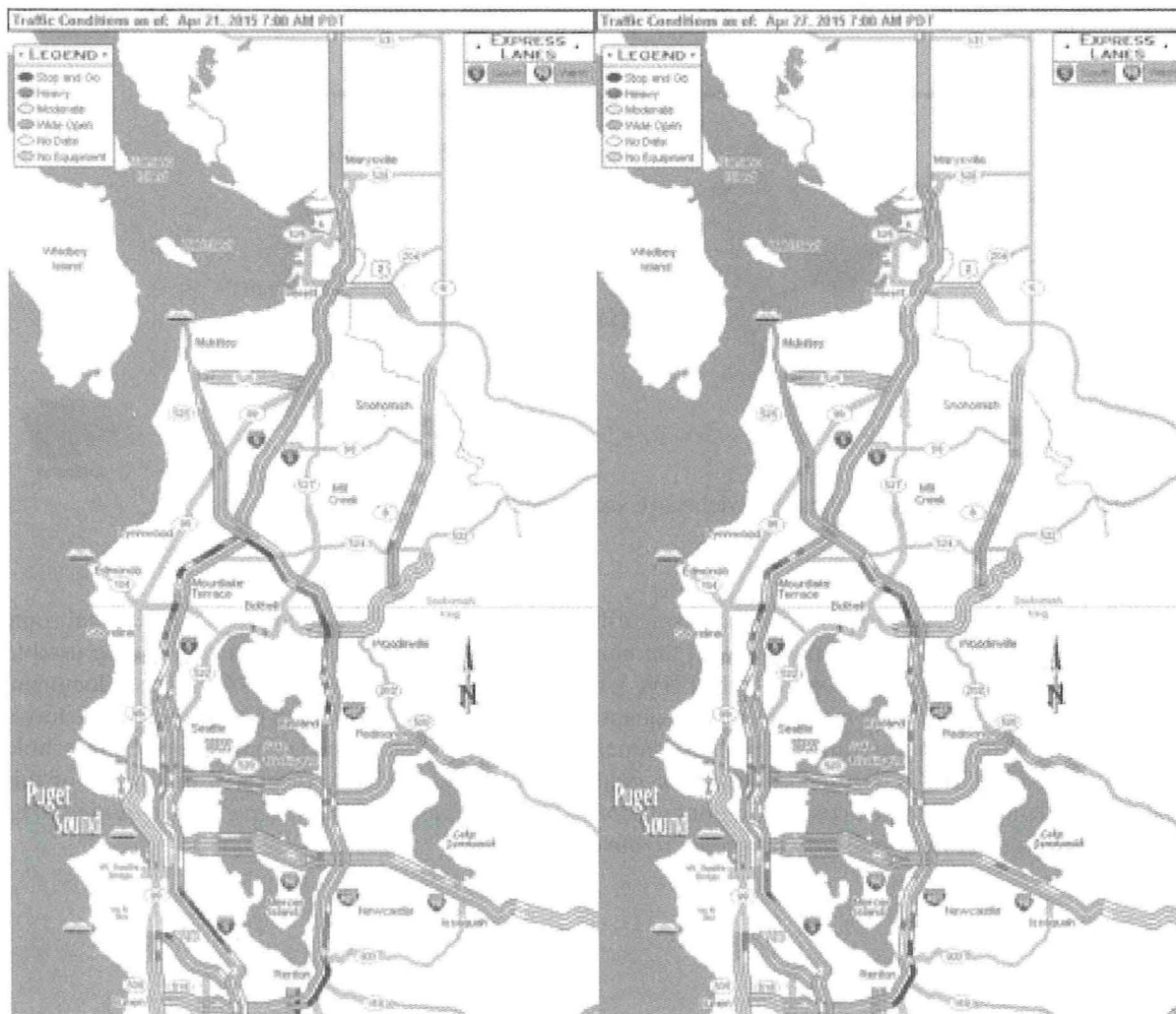


FIGURE A.2. Washington State Department of Transportation congestion maps (WSDOT).

¹ <http://www.wsdot.wa.gov/data/tools/traffic/maps/archive/?MapName=SysVert>.

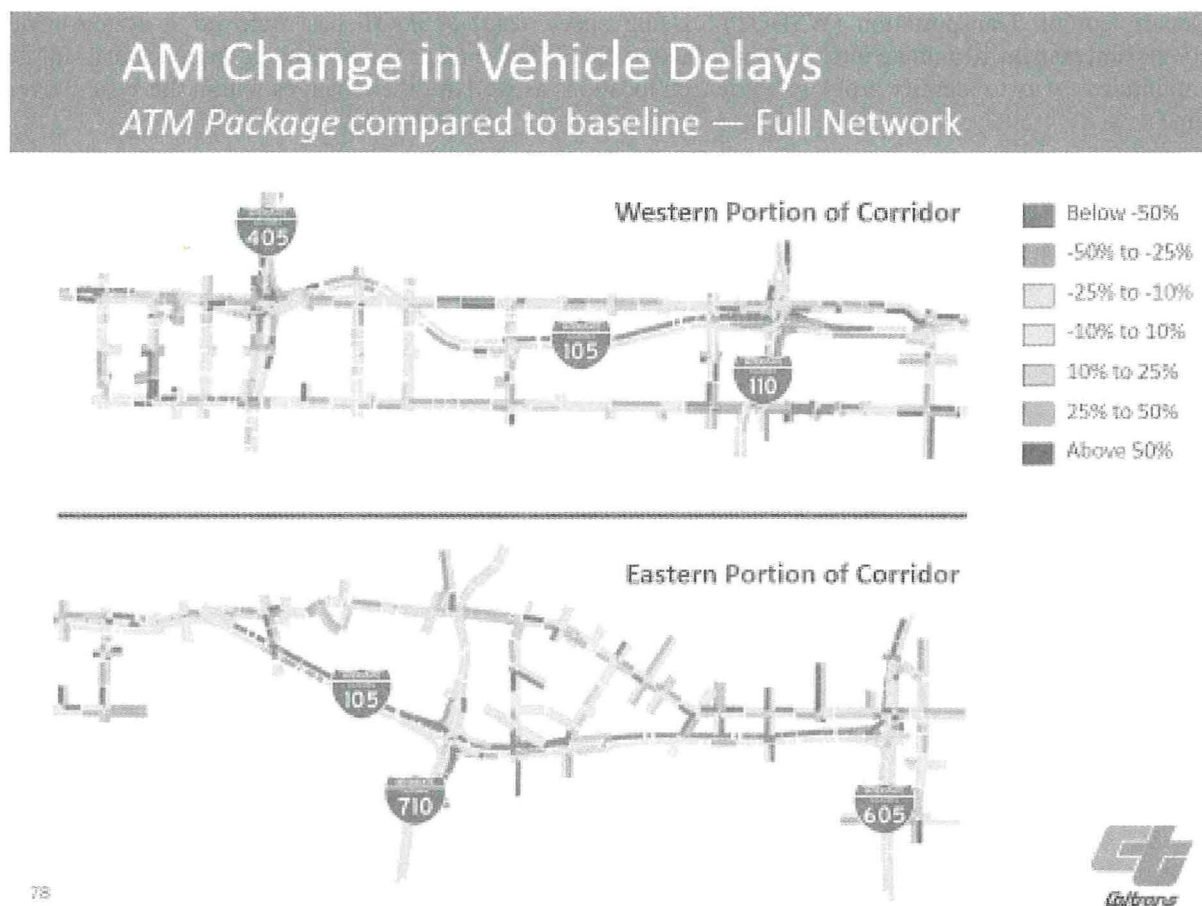


FIGURE A.3. Comparison of change in delays (Cambridge Systematics).

Reliability Profile

A within-day time-variant travel time chart is an effective way to convey systemwide or individual route travel time reliability. When combined with the number of delivered trips these data can also be used to measure and report reliable throughput. The FHWA Travel Time Reliability Measures Guidance² document suggests a set of performance measures used to quantify travel time reliability: 90th or 95th percentile travel time, buffer index, planning time index, and frequency that congestion exceeds some expected threshold (as shown in FIGURE A.4). According to the guide, travel time reliability measures the extent of this unexpected delay and provides this definition: *the consistency or dependability in travel times, as measured from day-to-day and/or across different times of the day.*

² http://ops.fhwa.dot.gov/publications/tt_reliability/.

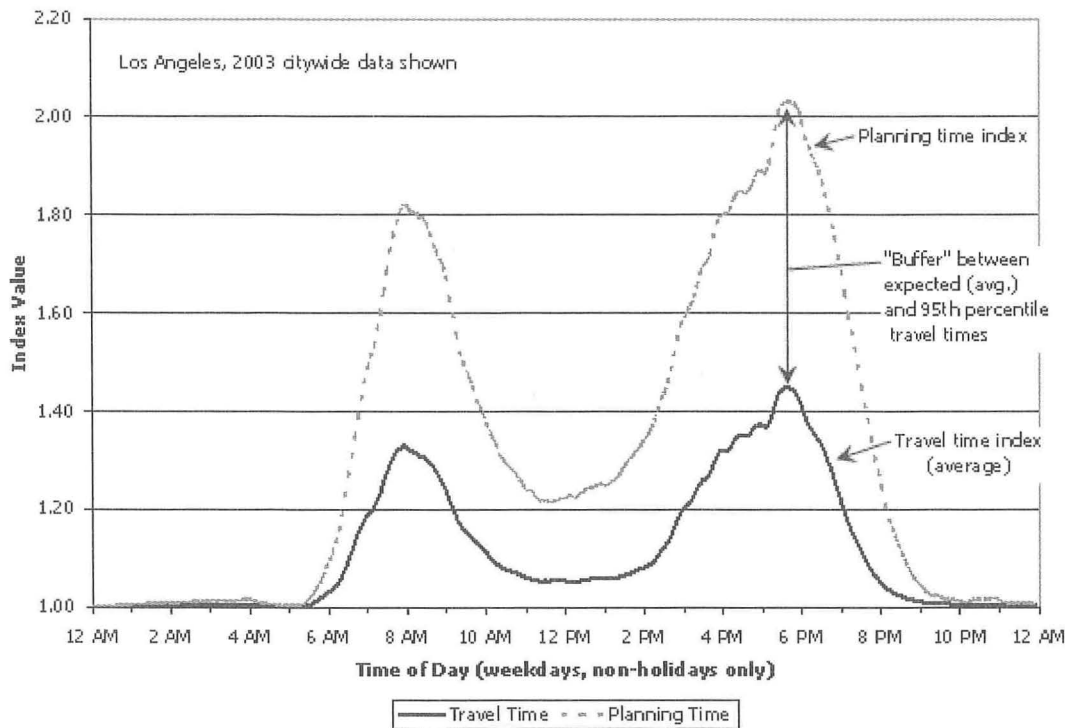


FIGURE A.4. Reliability measures are related to average congestion measures (USDOT).

Safety Profile

Common safety measures include crash rates and number of fatalities, which can be acquired directly from state or local agency databases. Similar to a congestion profile, a geographic illustration can be an effective way to identify the problem locations. In the KC Scout Annual Report³, as shown in FIGURE A.5, KC Scout uses a heat map to illustrate the locations of multiple-vehicle incidents in 2013 to identify severe/high incident rate locations intuitively.

³ KC Scout FY 2013 Annual Report. <http://www.kcscout.net/downloads/Reports/Annual/AnnualReport2013.pdf>.

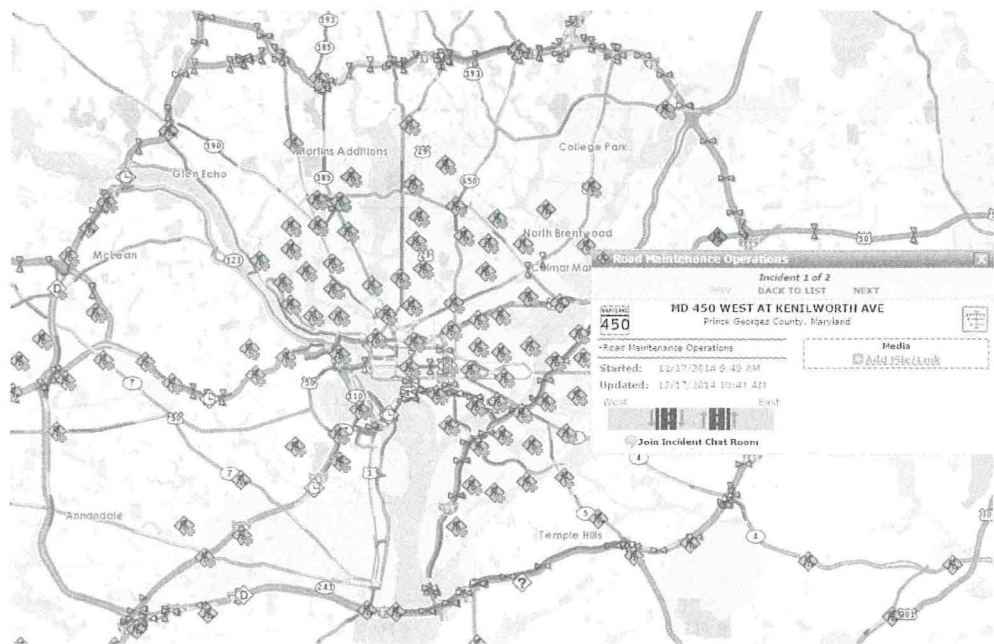


FIGURE A.5. Top multi-vehicle incident locations by route (KC Scout).

FIGURE A.6 and FIGURE A.7 depict accident per million vehicle miles and accident rates by location for a California freeway.

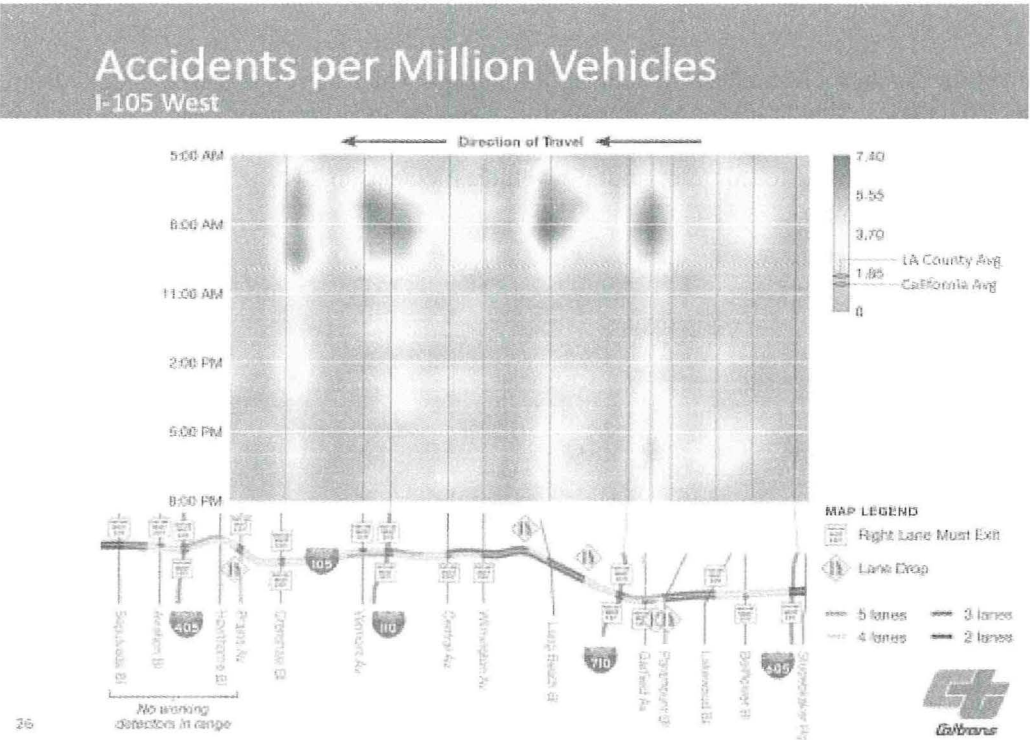


FIGURE A.6. Accident rates in space and in time (Cambridge Systematics).

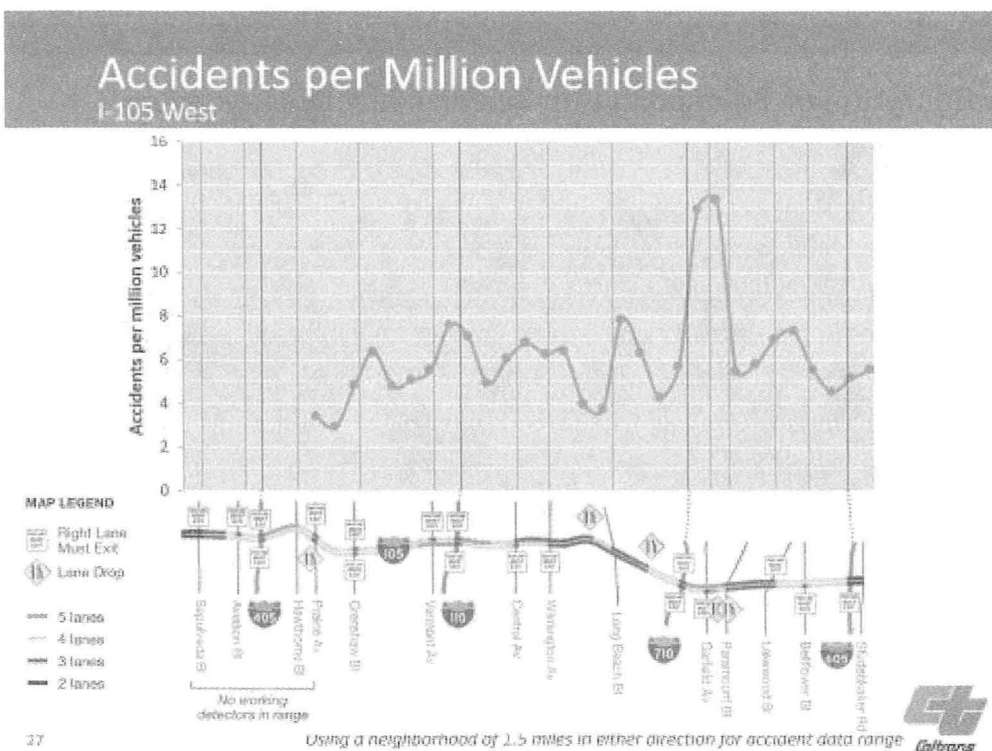


FIGURE A.7. Accident rates by location (Cambridge Systematics).

Observations about the performance of the system can come from many different viewpoints: from system managers who observe the buildup and dissipation of congestion through graphical displays and camera images, from agency staff who maintain the system, from the public safety officers who traverse the system, and from travelers themselves. When something is not “right” or when system dynamics change, there are likely stakeholders within the system who will note that something out of the ordinary is happening. Whether this insight comes from direct, hypothesis-oriented engagement with data or the experience observing or traversing the transportation system, it is important to establish processes and relationships that pull together insights from diverse stakeholders. Combining insights from individual observations and the analysis of data can lead to powerful and effective outcomes with respect to understanding system dynamics.

Key Performance Measures and Data Needs

Refer to Appendix D for definitions, geographic and temporal scales, and relevant statistical tests of key performance measures. Refer to Appendix F for an example data collection plan used for the San Diego I-15 ICM project.

Performance measurement has received recent attention as a focal point for improved transportation system management. The FHWA Office of Transportation Performance Management⁴ offers a website with resources intended to assist transportation system managers in creating and refining systemwide Transportation Performance Management (TPM) capabilities as shown in FIGURE A.8. Many agencies are working to enhance their TPM capabilities in advance of expected national rulemaking related to performance management.

⁴ <http://www.fhwa.dot.gov/tpm/>.

FHWA Definition of Transportation Performance Management

TPM, a strategic approach that uses system information to make investment and policy decisions to achieve national performance goals...

- Is systematically applied, a regular ongoing process
- Provides key information to help decision makers allowing them to understand the consequences of investment decisions across multiple markets
- Improving communications between decision makers, stakeholders and the traveling public.
- Ensuring targets and measures are developed in cooperative partnerships and based on data and objective information

FIGURE A.8. Definition of transportation performance management (USDOT).

The primary function of a transportation system is to facilitate the movement of people and goods. The inherently positive “products” of the system are completed trips, goods moved from one place to another, and travelers delivered to their destinations.

Early in an ICM project, the project team must define performance measures in line with the project objectives, mitigation strategies under consideration, and operational conditions (shaped by the understanding of available data) identified for the project. In order to begin to understand how the proposed transportation improvements will perform and whether they will meet stakeholder expectations, and even to help stakeholders develop realistic expectations for the improvements, project managers must first be willing to articulate them. Performance measures should be closely tied to the identified overall project goals and objectives and the expected traveler responses. For many improvement strategies, it is important to consider a set of performance measures that are sensitive to recurring as well as non-recurring congestion.

An effective way to identify appropriate performance measures is to develop one or more specific hypotheses to be tested for each objective. These hypotheses either can indicate a change in travel conditions, such as, “The strategies will reduce travel times during an incident by five percent,” or can be neutral in the prediction of an impact, such as “The strategies will not result in a change in emissions rates.” Performance measures that support the testing of the formulated hypothesis should then be identified. Use of this method ensures that the performance measures are appropriately mapped to the project goals and objectives.

To be able to compare different investments within a study area, it will be important to define and apply a consistent set of performance measures. The performance measures should:

- Provide an understanding of travel conditions in the study area including both localized and system-wide metrics representing impacts in both the immediate vicinity of the proposed improvement as well as representing impacts in the larger study area.
- Be consistent with lead agency overall performance measures used to evaluate all sorts of transportation improvements.

- Demonstrate the ability of improvement strategies to improve mobility, throughput, and travel reliability based on current and future conditions.
- Help prioritize individual investments or investment packages within the study area.

To the extent possible, the measures selected should be reported for the overall system and by:

- Mode—Single-Occupancy Vehicles (SOV), High-Occupancy Vehicles (HOV), transit, freight, non-motorized, etc.
- Facility Type—Freeways, expressways, arterials, local streets, etc.
- Jurisdiction—Region, county, city, neighborhood, and study area-wide.

Performance measures will typically focus on the following key areas described below. However, customized measures may be selected based on unique impacts of individual mitigation strategies. The key performance areas are:

- **Mobility.** Mobility describes how well people and freight move in the study area. Mobility performance measures are readily forecast. Three primary types of measures are used to quantify mobility, including travel time, delay, and throughput. Travel time and delay are straightforward to calculate. Throughput is calculated by comparing travel times under the incident scenarios to those under no incident—by comparing the percentage of trips under the same threshold travel time in both the pre- and post-mitigation scenarios, the relative influence of the strategies on reducing extreme travel times can be estimated.
- **Reliability and Variability of Travel Time.** Reliability and variability capture the relative predictability of the public's travel time. Unlike mobility, which measures how many people are moving at what rate, the reliability/variability measures focus on how mobility varies from day to day. Travel time reliability/variability is typically reported in terms of changes in the Planning Index and changes in the standard deviation of travel time.
- **Transportation Safety** is another performance area that may be of interest to transportation analysis. Safety is typically measured in terms of accidents or crashes in the study area, including fatalities, injuries and property damage only accident. Currently available safety analysis and prediction methodologies are not sensitive to transportation improvement strategies. At best, available safety analysis methods rely on crude measures such as V/C, or rely on empirical comparison methods such as identifying safety benefits resulting from the implementation of a certain type of mitigation strategy and then applying the same expected improvement rate to a future implementation of the same or similar strategy. Clearly, this is an area deserving new research.
- **Emissions and Fuel Consumption.** Emissions and fuel consumption rates are used to produce estimates based on variables such as facility type, vehicle mix, and travel speed.
- **Cost Estimation.** Planning-level cost estimates include life-cycle costs including capital, operating, and maintenance costs. Costs are typically expressed in terms of the net present value of various components. Annualized costs represent the average annual expenditure that is expected in order to deploy, operate, and maintain the transportation improvement and replace equipment as they reach the end of their useful life.

Data Requirements

The precise data requirements for calculating performance measures will vary depending on the performance measure; however, they all require basic inputs, including:

- Roadway geometry.
- Traffic control data.
- Travel demand, traffic volumes, and intersection turning movements.
- Performance data, such as queue locations, queue lengths, travel times, and speeds.
- Data on vehicle characteristics, such as vehicle classifications or vehicle mix.

The data requirements should be evaluated in the early inception stages of a project to get an early estimate of effort required. Quality/variability of existing data will affect sample sizes; therefore, early statistical evaluations of the data (Margin of Error) can prove highly valuable for subsequent development of effort required. Often, it is possible to use existing data, but these data may be outdated or from different timeframes for different parts of the network. In that case, resources need to be allocated for new data collection. If there is limited funding, resources need to be spent judiciously for collection of sufficient, quality data to conduct a study that would help inform decision-makers of the potential implications of their proposed transportation investments.

Data sources include the following:

- **Travel Demand**—The basic demand data needed are the entry volumes (i.e., the travel demand entering the study area) at different points of the network. At intersections, the turning volumes or percentages should be specified.
- **Origin-Destination (O-D)**—O-D trips can be estimated from a combination of travel demand model trip tables and from traffic counts. O-D data can be acquired from the local Metropolitan Planning Organization's (MPO) regional travel demand model. License plate matching surveys can be used to estimate hourly trips, but this is resource intensive. If the study area has transit, HOV and trucks in the vehicle mix, or if there is significant interaction with bicycles and pedestrians, the corresponding demand data would be needed.
- **Vehicle Characteristics**—Vehicle characteristics data can be obtained from the state DOT or air quality management agency, while National data can be obtained from car manufacturers, the Environmental Protection Agency (EPA), and the FHWA.
- **Traffic Control Data**—Data from traffic control devices at intersections or junctions are required. Control data refer to the type of control device (e.g., traffic signal, stop sign, ramp meter, etc.), the locations of these control devices, and the signal timing plans. Traffic control data can be obtained from the agencies that operate the traffic control devices in the given study area. Traffic operations and management data on links also are needed. These include location and type of warning signs—for lane drops, exits, guide signing; type and location of regulatory signs. If there are HOV lanes, information on the HOV lane requirement (HOV-2 versus HOV-3), their hours of operation, and the location of signs are needed; if there are HOT lanes, information on the pricing strategy is required.

- **Operational Conditions**—If there are Variable Message Signs (VMS) in the study area, the type of information that is displayed, the location, and if possible, the actual messages that were displayed are needed. Most of this information can be obtained from the public agencies responsible for operating the VMS. The type of signs and locations can be obtained from GIS files, aerial photographs, and construction drawings. Event data can be received from public agencies, such as the Traffic Management Center (TMC) logs. Crash databases should be verified since data may not always be recent and may not be for the specific study area. In addition, work zone data are usually available from State DOTs and weather data are available from the National Oceanic and Atmospheric Administration (NOAA).
- **Transit Data**—Transit data can be obtained from the local and regional transit operators—these data can include schedules and stop locations. Calibration data could include Transit AVL data, boarding and alighting data, and dwell time at stops.
- **Mobile Source Data**—Mobile source data include data derived from mobile phones, bluetooth devices, and other mobile sources—these can be used to augment other data collected. The primary type of data obtained from mobile sources are speeds and travel times. In most cases, the mobile source techniques use samples of vehicles in the traffic stream, but they may not be reliable sources for traffic counts and vehicle composition. The mobile source data are typically obtained, stored and sold by private vendors.

Going through a systematic process of collecting the critical data, verifying data quality, and documenting any assumptions are key to justifying the results of a study to decision-makers and the public. A statistical analysis of collected and previously available data can be helpful in determining the statistical data variability and the margin of error contained in the data.

Typical challenges with data include:

- **Data Comprehensiveness**—Comprehensive data cover different performance measures (volumes, speeds, bottlenecks, queuing, and congestion data) across freeways and arterial streets, as well as transit data and incident data. Traffic counts should be taken at key locations in the study area—key locations include major facilities (freeway segments, major intersections and interchanges, and major on- and off-ramps). If possible, data collection should be done simultaneously at all key locations. Otherwise, the counts should be taken at least during similar timeframes with similar demand patterns and weather conditions.
- **Data Reliability**—Automated data sources are often best for collecting the long-term data necessary to calculate reliability metrics; however, many existing automated data collection systems lack the robustness or reliability to compile relevant data sets effectively. A thorough assessment of the data quality from all sources is recommended to identify any potential problems early on in the process and establish methods to address any deficiencies.
- **Accuracy** is the measure of the degree of agreement between data values and a source assumed to be correct. It also is defined as a qualitative assessment of error. It is important to have accurate, internally consistent, and recent data. With respect to data filtering and fusion, it is crucial to adopt standard ways to accept or reject field data, and to address data gaps and missing data.

A small Margin of Error in the collected data is required to increase the validity of analysis results. It is necessary to collect enough data points for each performance measure (volumes, speeds, etc.) so that the sample is an accurate representation of the mean and standard deviation of this performance measure.

Depending on the mean to standard deviation ratio and the desired margin of error, the required sample size may vary greatly.

Analysis and Evaluation Methods

This section includes a discussion of several common methods for evaluating the extent, severity, and/or impact of recurrent and non-recurrent congestion, along with methods for analyzing their causes. Unlike traditional corridor studies, which often focus on a specific element of a corridor (i.e., a freeway or freeway and frontage road during a specific time of day), ICM analysis is a comprehensive approach that analyzes different operational conditions across time and transportation modes and across a large enough geographic area to absorb all impacts.

The complexity involved in ICM analysis goes far beyond what is typically required for more traditional types of transportation investments. The potential inclusion of multiple facility types (freeway and arterial) and multiple transportation modes, combined with the potential for road use pricing influences, complicates the analysis. The focus of the ICM strategies on non-typical operational scenarios (e.g., high demand, incidents, and inclement weather) adds further complexity to the assessment. Finally, the ICM analysis methodology enables a more sensitive analysis of corridor-level performance. Traditional travel demand models are sufficient for analyzing the impacts of major infrastructure investments, such as new freeways. However, when agencies are interested in fine-tuning transportation operations strategies to produce systemwide improvements that optimize existing infrastructure performance, they need time- and space-dynamic tools that are more sensitive and that enable insight into the benefits that are otherwise too marginal to see in traditional modeling.

One of the defining features of the ICM analysis methodology is that it enables agencies to understand system dynamics at the corridor level. The ICM analysis methodology uses corridor-level performance metrics in addition to the facility-level metrics to evaluate and understand corridor performance. The ICM analysis methodology accomplishes this through the combined use of multiple classes of available modeling tools. By combining aspects of macroscopic simulation (i.e., travel demand modeling (TDM), good for analyzing implications associated with mode shift), mesoscopic simulation (utilized to analyze regional strategies such as traveler information and pricing), and microscopic simulation (ideal for analyzing traffic control strategies), the ICM analysis methodology enables robust hypothesis modeling under a range of operating conditions of interest to the corridor for more informed decision-making. This produces improved analysis as compared to travel demand models alone because the combined tools yield more accurate travel times and speeds through the corridor, more in-depth understanding of bottleneck locations and their root causes, and an understanding of the influences beyond the periphery of the corridor that underlie corridor demand. The use of the different models allows specific strengths of the individual models to be combined: travel demand models provide estimates of long-term travel demand changes resulting from capacity changes, while more focused meso- and microsimulation models assess short-term operational impacts during specific non-recurring congestion conditions.

The ICM analysis approach should be implemented in conjunction with the ICM system development and design process to provide a tool for continuous improvement of corridor performance. Regular periodic conduct of ICM analysis also supports continuous improvement of the supporting ICM system. As the analysis process continues in parallel with the ICM system development and design process, it is likely that new strategies, alternatives and scenarios will emerge that will need to be evaluated within the analysis process; therefore, the flexibility to foresee and account for several iterations of analysis is critical. The design process may reveal new strategies or alternatives that may need to be analyzed, prompting modifications to the analysis structure. Likewise, the ICM analysis process may reveal parts of the concept

of operations that are unworkable or uncover opportunities that may be leveraged that result in changes to the ultimate ICM design.

The Value of Integrated Corridor Management Analysis

Investing in ICM analysis is a major undertaking that requires stakeholders to agree to the value proposition. Certainly, the ICM analysis methodology can provide valuable insight into the potential cost-benefits of ICM. The specific cost-benefit analysis results will vary by corridor. However, the general value of conducting ICM analysis is the extent to which it assists corridor stakeholders implementing ICM to

- **Invest in the right strategies**—ICM analysis offers corridor managers a predictive forecasting capability that they lack today to help them determine which combinations of ICM strategies are likely to be most effective and under which conditions:

Analysis helps decision-makers identify technical and implementation gaps, evaluate ICM strategies, and invest in the combination of strategies that would most minimize congestion and produce the greatest benefits. Comprehensive modeling increases the likelihood of ICM success and helps minimize the unintended consequences of applying ICM strategies to a corridor. It provides an enhanced understanding of existing corridor conditions and deficiencies, allowing the improved ability to match and configure proposed ICM strategies to the situation at hand.

- **Invest with confidence**—ICM analysis allows corridor managers to “see around the corner” and discover optimum combinations of ICM strategies, as well as potential conflicts or unintended consequences inherent in certain combinations of strategies that would otherwise be unknowable before full implementation:

Analysis helps managers estimate the benefits resulting from ICM across different transportation modes and traffic control systems. Importantly, it helps managers to align these estimates with specific assumptions about corridor conditions and ICM strategies. Without being able to predict the effects of ICM strategies, corridor transportation agencies may not take the risk of making the institutional and operational changes needed to optimize corridor operations.

- **Lower risk associated with implementation**—Analysis facilitates the detailed development of concepts of operations and requirements by stakeholders, and helps corridor managers define and communicate key analysis questions, project scope, partner roles, and partner responsibilities. The analysis facilitates the development of concepts of operations and requirements by stakeholders in more detail, and helps corridor managers understand in advance what questions to ask about their system and potential combinations of strategies to make any implementation more successful:

The development of an ICM analysis plan may help identify flaws or technical issues in the Implementation Plan or Concept of Operations (CONOPS) that may have been otherwise overlooked. The ICM analysis helps to communicate the scope of the project and appropriately set expectations among differing project stakeholders (e.g., planners, operators, data analysts, modelers, and agency management from State, local, and/or regional transportation agencies), and provides a clearer definition of expected roles and responsibilities. Analysis also helps managers identify and prioritize resources to project objectives, allowing for the effective and efficient allocation of resources and more sound project management.

The Integrated Corridor Management Analysis Process

FIGURE A.9 presents the five major work steps, summarized below, associated with implementing the Integrated Corridor Management (ICM) Analysis, Modeling, and Simulation (AMS) methodology, as specified in the FHWA Traffic Analysis Tools Guide Volume XIII. This appendix of the ICM Guidebook borrows heavily from the ICM AMS Guide. Refer to Appendix E for more details on each work step.

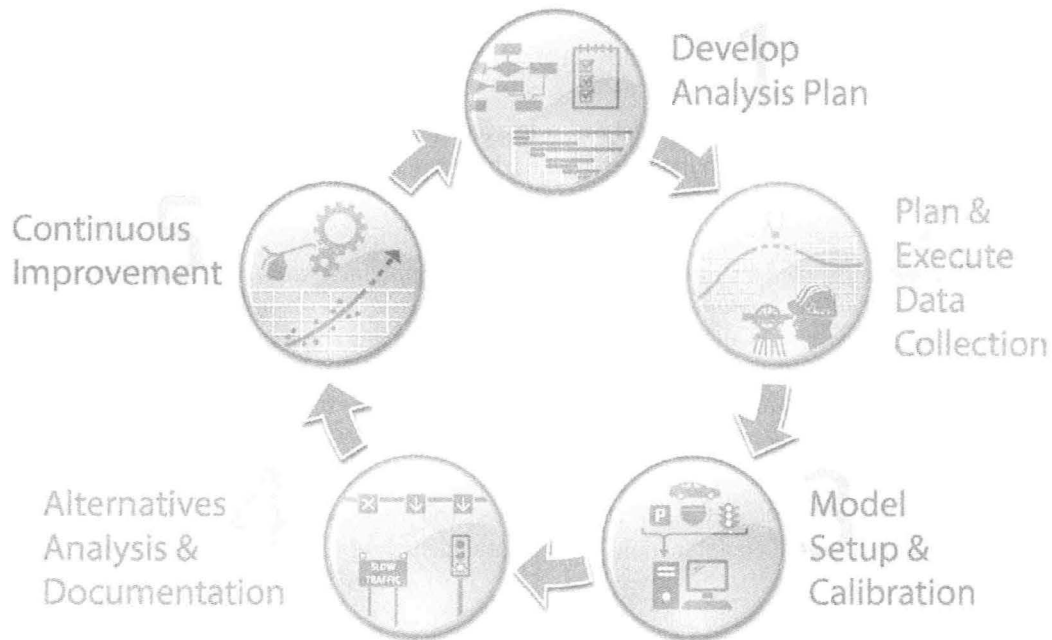


FIGURE A.9. Integrated Corridor Management Analysis, Modeling, and Simulation Approach Work Steps (Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc., 2017).

The five ICM analysis work steps include:

1. **Develop Analysis Plan**—The analysis plans provide a valuable tool for communicating the scope of the project. The analysis plan typically includes initial planning and scoping and then iterative updates to assumptions, scope, and agreements as the project moves forward. The development of the analysis plan is the primary mechanism for securing a clear and mutual understanding among stakeholders of expectations and assumptions. It may help to identify flaws or technical issues in the ICM Concept of Operations (CONOPS) that may have been otherwise overlooked. The analysis plan confirms not only the stakeholder agreements regarding the scope of the ICM analysis, but also the most appropriate approach to the analysis based on an enhanced understanding of project objectives, the corridor conditions, the ICM strategies being implemented, and the available tools and data. The contents of the Analysis Plan include: Project definition, Geographic and temporal scope, Selecting the appropriate analysis tool, Performance measures to be used in the analysis, Data requirements, Analysis tool calibration criteria and expectations, Alternatives to be studied including analysis scenarios and transportation mitigation strategies, and Expected cost, schedule and responsibilities for the analysis. The benefits of completing this work step include a better allocation of resources appropriate to the study objectives; a clear and shared understanding of roles, responsibilities, and expectations among project participants; and the ability of project participants to

communicate the project vision to the broader stakeholders effectively. It also helps maintain agreement and project continuity as stakeholders leave positions and new staff comes in mid-stream.

2. **Develop Data Collection Plan and Collect Data**—The purpose of this work step is to collect the needed data to support the desired analysis cost effectively. In this step, project partners research data needs and availability, identify available data as well as gaps and methods to address those gaps where possible, compile and archive needed data, collect data, and perform quality control on the collected data. The successful completion of this task will support high confidence in AMS through the collection of appropriate, high-quality data using the most effective and efficient methods. Doing this well can substantially reduce costs both downstream and in continual process improvement.
3. **Model Setup and Calibration**—The purpose of this step is to configure the model(s) and analysis tools to reflect the agreed-upon objectives, scope, and parameters of the analysis and to verify proper model calibration to support accurate results. In this step, the baseline model network is developed, including all relevant transportation facilities and modes. In addition, baseline demand modeling is conducted, and the simulation models are calibrated. This step also includes testing sensitivity of the model to understand limitations of the analysis better. This work step can often be the most time- and resource-demanding of the AMS process. Successful completion of this work step will ensure the integrity of the developed models and the efficient use of valuable resources, and will support risk management for this critical step.
4. **Alternatives Analysis and Documentation**—The purpose of this step is to identify the optimum combination of ICM strategies for various operational conditions (e.g., varying roadway congestion and transit demand levels; incident conditions; weather conditions affecting operations; presence of work zones; special events) to support effective ICM. This step includes developing future baseline model networks and trip tables for all operational conditions and conducting the alternatives analysis for all ICM strategies. This step assumes that preliminary strategies/alternatives screening has already been performed using sketch planning or other iterative examinations. The outcomes of this project will include an understanding of predicted effects (including unintended consequences) for various hypotheses of interest, prioritization of ICM alternatives, and a quantified understanding of project benefits and costs. The results will inform ICM deployment decisions and can help build support among broader stakeholders for the ICM system.
5. **Continuous Improvement**—In this step, practitioners reassess models, model calibrations, and results against observed conditions to validate the analysis approach. Lessons learned are used to improve the process for future deployments, and ongoing performance measurement is used to refine the efficiency of the ICM. This step is ongoing, and consists of the repetition of this process in a manner that reflects and incorporates the data gathering and lessons learned from previous steps.

Overview of Integrated Corridor Management

Integrated Corridor Management (ICM) involves the coordination of transportation management techniques among networks in a corridor that can collectively address congestion and improve overall corridor performance. The United States Department of Transportation (USDOT) ICM program demonstrates how Intelligent Transportation Systems (ITS) technologies can efficiently and proactively manage the movement of people and goods in major transportation corridors.

Overview of Integrated Corridor Management

One area of transportation operations that has the potential for increased efficiency lies in how transportation agencies coordinate day-to-day operations along heavily traveled corridors. Along most urban transportation corridors, each transportation agency within the corridor (e.g., local departments of transportation, bus operators, light rail operators, etc.) handles operations independently, with the exception of incidents or planned events. As road users experience increased levels of congestion, delay, and incidents, this operational model has become less effective in meeting the transportation needs of the people that rely on the corridor.⁵

ICM is an approach to improving transportation that takes into account all elements in a corridor, such as highways, arterial roads, and transit systems. By optimizing the use of existing infrastructure assets through coordinated transportation management techniques, transportation investments can go farther. There are many corridors in the country with underutilized capacity (in the form of arterials, freeway travel lanes and parallel transit capacity (e.g., bus, rail, bus rapid transit, etc.)) that could benefit from ICM. The maturation of ITS technologies, availability of supporting data, and emerging multiagency institutional frameworks make ICM practical and feasible. There is a large number of freeway, arterial, and transit optimization strategies available today that are already in widespread use across the United States. Most of these strategies are managed locally by individual agencies on an uncoordinated basis. Even those managed regionally are often managed in isolation (asset-by-asset) rather than in an integrated fashion across a transportation corridor.

Dynamically applying these strategies in combination across a corridor in response to varying conditions is expected to reduce congestion “hot spots” in the system and to improve the overall productivity of the system. Furthermore, providing travelers with actionable information on alternatives (such as multimodal comparative travel times) is expected to mitigate bottlenecks, reduce congestion, improve the resilience of the system during major incidents, and empower travelers to make more informed travel choices.

Typically, the key champions of ICM are State DOTs and metropolitan planning organizations (MPOs). These multijurisdictional agencies have the authority and resources to manage ICM corridors as

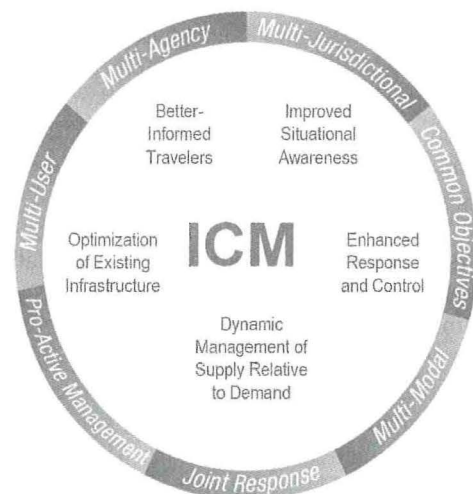
⁵ Federal Highway Administration, *Integrated Corridor Management and Transit and Mobility on Demand*, FHWA-HOP-16-036. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16036/fhwahop16036.pdf>.

collaborative, multimodal systems. Assets owned and operated by these agencies include, but are not limited to, advanced traffic management systems, ramp meter information systems, managed lane/HOV control systems, 511 traveler information systems, changeable message sign systems, camera surveillance systems and regional event management systems. These systems provide the necessary intelligent transportation system foundation for integrated corridor management.

Metropolitan areas that are considering ICM will likely have formal or informal operations planning groups from which to build an ICM team. The question of who should be involved should be left to the participants themselves. It is important to keep all stakeholders informed throughout the process, even when they are not directly involved. Continued involvement of all stakeholder groups will add significant value to the project—from adding precision to the design and informing traveler demand modelers, to proactively addressing agency regulations. Interagency agreements between stakeholders are typically required in situations where infrastructure assets and information exchange is shared between agencies. Institutional, organizational, and technical arrangements will be further explored in Appendix H.

FIGURE B.1 depicts the expected functionality of an ICM system, which typically involves three distinct yet interrelated types of integration:

- Institutional integration relates to coordination and collaboration between various agencies and jurisdictions that transcends institutional boundaries.
- Operational integration refers to multiagency and cross-network operational strategies to manage the total capacity and demand of the corridor.
- Technical integration refers to sharing and distribution of information, and system operations and control functions to support the immediate analysis and response to congestion.



In 2007, the U.S. DOT partnered with eight “Pioneer Sites,” selected to explore the institutional guidance, operational capabilities, ITS technology, and technical methods needed for effective ICM. In 2008, three of the Pioneer Sites (Dallas, TX; Minneapolis, MN; and San Diego, CA) were selected to conduct AMS of their ICM concepts. Two sites (Dallas, TX and San Diego, CA) were selected to demonstrate their ICM systems by the end of 2015. The Dallas site ICM program centered on the transit offerings of the Dallas Area Rapid Transit (DART) system. The San Diego site includes a Bus Rapid Transit (BRT) system as a critical part of their ICM deployment. Post-deployment assessment of the two Pioneer Demonstration sites showed a 0.1 percent and 3.3 percent reduction of delay along the study corridor in Dallas and San Diego, respectively. Both study corridors showed benefits in travel time reliability during peak periods as well.⁶

FIGURE B.1. Functionality of an Integrated Corridor Management system (FHWA).

⁶ U.S. DOT Office of the Assistant Secretary for Research and Technology, *Integrated Corridor Management Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas Post-Deployment Assessment Report*, FHWA-JPO-16-396. Available at: <https://ntl.bts.gov/lib/60000/60400/60490/FHWA-JPO-16-396.pdf>; U.S. DOT Office of the Assistant Secretary for Research and Technology, *Integrated Corridor Management Analysis*,

Recently, over 40 new sites applied for ICM grants, signifying a great demand for ICM. In February of 2015, 13 sites were selected by the U.S. DOT to receive grants to expand the ICM program focusing on developing Concepts of Operations, Requirements, and Analysis Modeling and Simulation Plans for their sites. Five of these sites specifically called out freight or transit in their corridor descriptions. The map in FIGURE B.2 highlights the expansion of ICM activities nationwide.

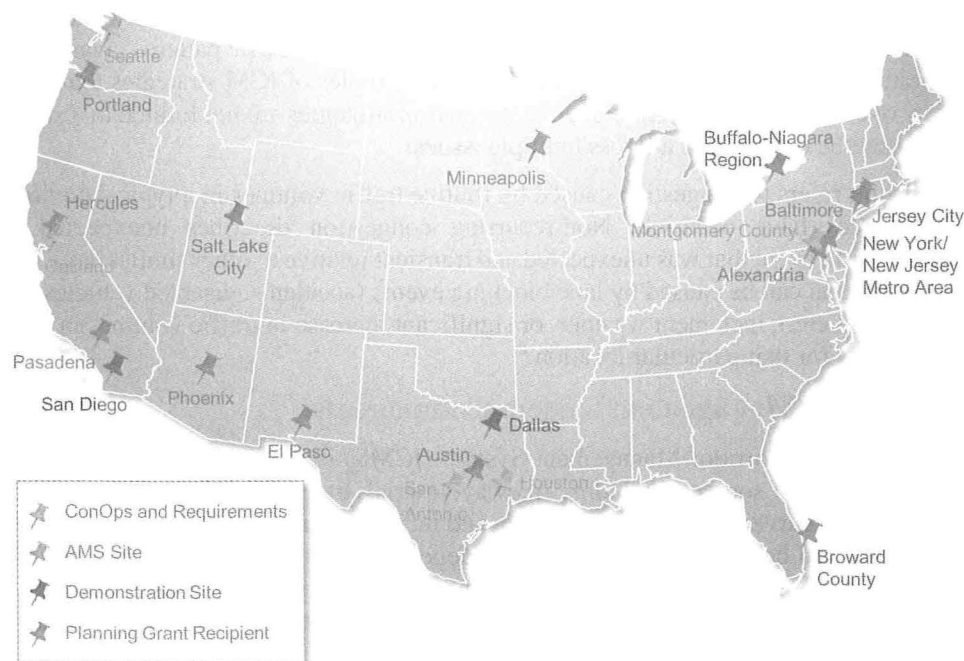


FIGURE B.2. Nationwide Integrated Corridor Management activity as of August 2017 (<https://www.fhwa.dot.gov/pressroom/fhwa1504.cfm>).

Integrated Corridor Management Strategies

ICM combines two fundamental concepts: active management and integration. Active management involves monitoring and assessing the performance of the system and dynamically implementing actions in response to fluctuations in demand. In an ICM corridor, all individual facilities must be actively managed so that operational approaches can be altered in real-time in response to an event anywhere on the system.⁷

The broadness, versatility, and complexity of ICM is apparent when trying to compile a comprehensive list of potential ICM strategies. At a basic level, the goals of ICM projects involve:

- Improving travel time.
- Increasing corridor throughput.

Modeling, and Simulation for the I-15 Corridor in San Diego, California Post-Deployment Assessment Report, FHWA-JPO-16-403. Available at: <https://ntl.bts.gov/lib/61000/61100/61131/FHWA-JPO-16-403.pdf>.

⁷ Federal Highway Administration, *Integrated Corridor Management and Traffic Incident Management: A Primer*, FHWA-HOP-16-035. Available at: <https://ops.fhwa.dot.gov/publications/fhwahop16035/fhwahop16035.pdf>.

- Improving travel time reliability.
- Improving incident management.
- Enabling intermodal travel decisions.
- Safety for all travelers.

There is no standardized set of ICM strategies to include in an ICM project. Ultimately, the ICM strategies chosen for a specific corridor will depend on a range of factors such as traffic patterns, available assets, and agency collaboration. TABLE B.1 and TABLE B.2 present samples of ICM strategies that can be used to mitigate an array of corridor deficiencies. Potential mitigation strategies are not limited to a single observed deficiency—they can be designed to address multiple issues.

Recurring congestion refers to congestion caused by routine traffic volumes in a typical environment—no unusual circumstances have occurred. Non-recurring congestion describes unexpected or unusual congestion caused by an event that was unexpected and transient relative to other similar days. For example, non-recurring congestion can be caused by lane blocking events (accidents, disabled vehicles, debris in the roadway, construction, etc.), inclement weather, or significant increase in traffic volumes in comparison to typical traffic volumes for that particular location.⁸

Integrated Corridor Management System Components

The role of the Integrated Corridor Management System (ICMS) is to ingest, integrate and analyze data from a comprehensive set of sources, including freeway, arterial, transit, traveler information, commercial vehicle operation, traffic surveillance and monitoring, and incident management systems. FIGURE B.3 lists potential systems that can be connected to the ICMS, depending on the availability and need of the ICM strategies selected for implementation. ICMSs are generally connected to existing, upgraded, and new systems. Communication to the ICMS can be one-way (data feeds into the ICMS) or two-way (the ICMS also sends data to the system).

Value of Integrated Corridor Management

Key lessons learned from agencies that have implemented ICM are presented in this section. While quantitative assessments of proposed ICM solutions show annual travel time savings, improvement in travel time reliability, annual fuel savings, annual emissions reductions, and 10-year net benefit estimates, ICM projects are not without their challenges and limitations. Agencies looking to pursue ICM projects should be fully informed of what it will involve.

Pros

Transportation researchers have used Analysis, Modeling and Simulation (AMS) methodologies to estimate the impacts of proposed ICM solutions (see TABLE B.3). Projected benefit-cost ratios range from 10:1 to 22:1 over a 10-year period.

⁸ U.S. DOT ITS Joint Program Office, *Integrated Corridor Management Concept Development and Foundational Research Phase 1 – Concept Development and Foundational Research*, FHWA-JPO-06-034. Available at: https://ntl.bts.gov/lib/jpodocs/repts_te/14273_files/14273.pdf.

TABLE B.1. Potential Integrated Corridor Management strategies for freeways.

Observed Deficiency	Potential Mitigation Strategies	Description	Potential Benefits
Safety/Crashes	Improved Dynamic Corridor Ramp Metering Algorithms	Dynamic adjustment (up or down) of metering rates based on current conditions on the facility and remaining available capacity of the facility/system.	<ul style="list-style-type: none"> • Increase throughput • Decrease vehicle hours traveled • Decrease primary incidents • Increase speeds • Decrease travel times • Decrease delay
	Queue Warning	Inform travelers of the presence of downstream stop-and-go traffic based on real-time traffic detection using warning signs and flashing lights.	<ul style="list-style-type: none"> • Decrease primary and secondary incidents • Decrease speed variability
	Improved Decision Support Systems (DSS)/Incident Response Plans	DSSs use real-time data and knowledge of the current state/conditions of the network to provide appropriate alternate routes to TMC operators as they respond to incidents (e.g., traffic collisions, severe weather, evacuations).	<ul style="list-style-type: none"> • Reduce response time • Reduce negative impacts on network performance
	Media and Social Media Alerts	Mobile alerts for real-time traveler information such as congestion hot spots and locations of incidents, lane closures, and construction events can provide roadway users with actionable information.	<ul style="list-style-type: none"> • Decrease primary and secondary incidents • Decrease delay
Non-Recurring Congestion	Dynamic HOV Conversion	When congestion is light, the HOV lane can be operated as a general-purpose lane, and when congestion is severe, access can be limited to transit vehicles only. For facilities that lack dedicated HOV lanes, hard shoulder running can be used to add a general-purpose lane to the freeway, while the median lane is simultaneously converted into an HOV lane.	<ul style="list-style-type: none"> • Increase transit ridership • Increase transit on-time performance
	Speed Harmonization/Variable Speed Limits (VSL)	VSL is used to slow traffic down gradually ahead of a congested area to reduce the occurrence of traffic collisions, and attempts to set speed limits appropriately in the congested regions so that traffic continues to flow smoothly rather than deteriorating to less efficient stop-and-go conditions.	<ul style="list-style-type: none"> • Increase capacity • Decrease primary and secondary incidents • Increase average speed • Decrease peak-period duration

Observed Deficiency	Potential Mitigation Strategies	Description	Potential Benefits
	Dynamic Rerouting	Alternate route guidance is provided to drivers heading for designated destinations when conditions on the primary route have deteriorated below a prescribed threshold due to congestion, weather conditions, or other situations. This strategy is closely supported by effective DSSs.	<ul style="list-style-type: none"> • Decrease emissions • Decrease fuel consumption • Decrease travel time • Increase average speed • Decrease speed variability
	Media and Social Media Alerts	Mobile alerts for real-time traveler information such as congestion hot spots and locations of incidents, lane closures, and construction events can provide roadway users with actionable information.	<ul style="list-style-type: none"> • Decrease primary and secondary incidents • Decrease delay
Recurring Congestion	Lane Use Signals/Dynamic Lane Management	Opening and closing of lanes on a facility in response to real-time conditions. Congested conditions may result in the opening of additional lanes (such as reversible or shoulder lanes) to traffic. When closures occur, lane use signals provide drivers warning ahead of the closure so that they may anticipate the merge ahead.	<ul style="list-style-type: none"> • Increase throughput • Increase capacity • Decrease primary and secondary incidents • Decrease emissions
	Dynamic Pricing	Uses tolls to manage supply during periods of high demand. Prices are set to maintain a prescribed level of performance on the facility, such as a minimum acceptable speed. Provisions are sometimes enacted that allow HOVs and transit vehicles to receive discounted toll rates.	<ul style="list-style-type: none"> • Increase transit ridership • Increase transit on-time performance
	Dynamic Junction Control	Lane configurations at a ramp merge or diverge are updated throughout the day to best accommodate the current traffic demands (high entrance volumes and/or high exit volumes).	<ul style="list-style-type: none"> • Decrease ramp and mainline delays • Decrease mainline and ramp travel times • Decrease primary accidents
	Media and Social Media Alerts	Mobile alerts for real-time traveler information such as congestion hot spots and locations of incidents, lane closures, and construction events can provide roadway users with actionable information.	<ul style="list-style-type: none"> • Decrease primary and secondary incidents • Decrease delay

Source: Active Traffic Management Congestion Relief Analysis Study and <http://www.itsbenefits.its.dot.gov>.

TABLE B.2. Potential Integrated Corridor Management strategies for arterials.

Observed Deficiency	Potential Mitigation Strategies	Description	Potential Benefits
Safety/ Crashes	Emergency Vehicle Signal Preemption System	Emergency services vehicles (ambulances, fire trucks, police cars) equipped with sensors can trigger signalized intersections to synchronize traffic and crosswalk signals in the forward path, allowing them to pass through a corridor to reach the incident.	<ul style="list-style-type: none"> • Decrease travel time for emergency service vehicles • Reduce response time • Decrease secondary incidents
	Automated Work Zone Information System (AWIS)	The AWIS system uses a Central System Controller, highway advisory radios (HAR), traffic sensors, CMSs, and speed stations to calculate and report delay times to travelers via CMSs. The public is provided with general work zone and delay information via various traveler information sources (e.g., 511, HAR system).	<ul style="list-style-type: none"> • Decrease fatal crash rate • Decrease rear-end crash rate
	Improved Decision Support Systems (DSS)/Incident Response Plans	A DSS evaluates a set of business rules based on current traffic conditions (time of day, day of week, incident severity, location of the incident, possible issues with alternate routes) and determines the best predefined response plan which involves potential alternate routes, signal and metering light timing changes, equipment and personnel requests, and communication plans.	<ul style="list-style-type: none"> • Decrease response time • Decrease incident clearance time • Decrease delays • Decrease secondary incidents
	Media and Social Media Alerts	Mobile alerts for real-time traveler information such as congestion hot spots and locations of incidents, lane closures, and construction events can provide roadway users with actionable information.	<ul style="list-style-type: none"> • Decrease primary and secondary incidents • Decrease delay
Non-Recurring Congestion	Predictive Traveler Information	Travel time estimates are generated based on predicted (as opposed to recently observed) performance of the system, using models, expected incident clearance times, schedules of regional special events, etc. and are expected to be more reliable and accurate than those based on past data.	<ul style="list-style-type: none"> • Increase on-time performance
	Increased transit and parking capacity	New parking spots planned within the corridor can be used to attract single occupancy vehicle (SOV) trips to transit. Additional buses or light rail vehicles can be added as necessary to accommodate increases in demand. Financial incentives such	<ul style="list-style-type: none"> • Increase transit ridership • Decrease freeway and arterial travel time • Increase capacity

Observed Deficiency	Potential Mitigation Strategies	Description	Potential Benefits
		as reduction in fees for transit and parking may be incorporated into this strategy.	
	Dynamic Lane Reversal	A specialized and common form of dynamic lane management, this strategy involves the designation of a specialized lane (or lanes) on a facility to the direction of travel that would most benefit from its capacity according to current conditions. Some reversible lane facilities follow preset time-of-day schedules.	<ul style="list-style-type: none"> • Decrease travel time • Increase capacity • Decrease delay
	Media and Social Media Alerts	Mobile alerts for real-time traveler information such as congestion hot spots and locations of incidents, lane closures, and construction events can provide roadway users with actionable information.	<ul style="list-style-type: none"> • Decrease primary and secondary incidents • Decrease delay
Recurring Congestion	Coordination of Freeway Ramp Metering and Arterial Signal Control	Ramp metering and arterial signal control systems that are operated in isolation can lead to excess congestion. In a coordinated system, ramp-metering rates are generally used to inform signal operations on nearby arterials, so that their operations complement—rather than conflict with—each other.	<ul style="list-style-type: none"> • Decrease delays • Decrease travel time • Reduced emissions • Increase throughput
	Adaptive Traffic Signal Control	Operating a signalized intersection, corridor, or network of arterials such that the timing parameters are set based on current traffic conditions. These systems can respond reactively to atypical traffic conditions (e.g., high demands caused by special events), or proactively to anticipated recurrent congestion based on historical data.	<ul style="list-style-type: none"> • Decrease travel time • Decrease delay • Decrease number of stops
	Transit Signal Priority (TSP)	When a transit vehicle approaches a signalized intersection, TSP systems will attempt to give priority to the vehicle by extending the green phase until the vehicle passes through the intersection, or by reducing the duration of the red phase if it is already active.	<ul style="list-style-type: none"> • Decrease person-hours of delay • Increase transit ridership • Increase transit on-time performance • Decrease travel time • Decrease fuel consumption
	Media and Social Media Alerts	Mobile alerts for real-time traveler information such as congestion hot spots and locations of incidents, lane closures, and construction events can provide roadway users with actionable information.	<ul style="list-style-type: none"> • Decrease primary and secondary incidents • Decrease delay

Source: Active Traffic Management Congestion Relief Analysis Study and <http://www.itsbenefits.its.dot.gov>.

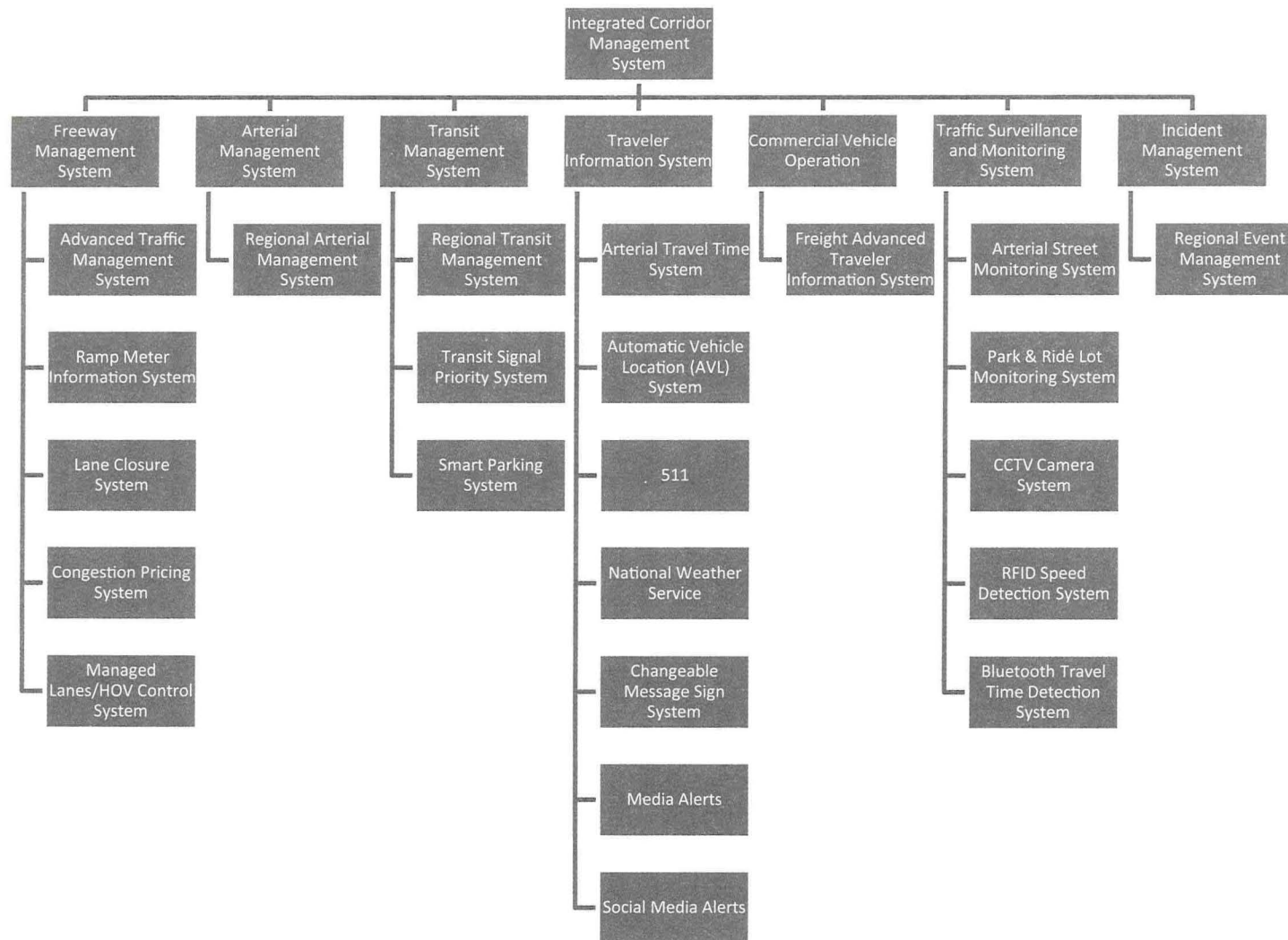


FIGURE B.3. Potential Integrated Corridor Management system components (San Diego Association of Governments and <http://www.topslab.wisc.edu/workgroups/icm/ICM%20Best%20Practices.pdf>).

TABLE B.3. Estimated pre-deployment benefits of Integrated Corridor Management.

Evaluation Measures	San Diego	Dallas	Minneapolis
Annual Travel Time Savings (Person-Hours)	246,000	740,000	132,000
Improvement in Travel Time Reliability	10.6%	3%	4.4%
Gallons of Fuel Saved Annually	323,000	981,000	17,600
Tons of Mobile Emissions Saved Annually	3,100	9,400	175
10-Year Net Benefit ¹	\$104 million	\$264 million	\$82 million
10-Year Cost	\$12 million	\$14 million	\$4 million
Benefit-Cost Ratio	10:1	20:1	22:1

¹The values of safety benefits were not included in San Diego, Dallas, and Minneapolis estimates.

Source: U.S. DOT, *Integrated Corridor Management (ICM) ITS Benefits, Costs, and Lessons Learned: 2017 Update Report*, FHWA-JPO-17-500. Available at:

http://www.itsknowledgeresources.its.dot.gov/its/bcllupdate/pdf/BCLL_Freeway_ICM_2017_FINAL.pdf.

Additional benefits cited by agencies involved in implementing complex multiyear and multi-agency ICM projects include:

- ICM provides the opportunity to proactively improve and maximize the performance of the transportation system by serving as an alternate to traditional major infrastructure investments that may be more expensive or constrained by environmental issues.⁹
- Proactive management of incidents and congestion helps to minimize negative impacts to network performance when faced with unexpected or unusual events.
- ICM solutions provide corridor users with real-time situational awareness (travel times, incident information, and expected delays) via traveler information sources, enabling travelers to make smarter travel decisions.
- ICM produces benefits across different operational conditions (recurrent and non-recurrent congestion).
- Developing relationships with other agencies that operate in the same corridor opens up opportunities for tackling overlapping transportation issues using coordinated efforts, shared resources, and different perspectives.

Cons

On a qualitative level, the following were cited as the top reasons that agencies were not pursuing ICM and operational strategies:

- A need to dedicate available funds to maintenance of existing infrastructure and initiatives.
- A prevailing sentiment that such strategies will not address the agency's or the region's transportation problems.
- A lack of any focused or concerted effort at the agency to motivate a shift from capital to operational strategies.

⁹ Feedback from Alex Estrella (San Diego Association of Governments), ICM Manager of the I-15 Demonstration Site.

- Incident response plans, as well as predictive models need to be updated and tested on a regular basis to ensure that they accurately reflect the ICM corridor demands, asset availability, and data feeds from various transportation management systems.

Elements of Integrated Corridor Management within Agency Operations

Many agencies are already performing some forms of ICM without explicitly labeling it as such. TABLE B.4 lists elements of ICM that may be recognized by other forms or terminology that agencies may be more closely familiar with, such as traffic incident management (TIM), transportation system management & operation (TSM&O), active transportation and demand management (ATDM), Smart Cities, and the general scope of transportation management centers (TMCs) and transportation operations centers (TOCs). ICM solutions are complementary to, and are further enhanced by related multidisciplinary, multijurisdictional, performance-driven initiatives such as these, as well as objectives-driven, performance-based planning for operations efforts.

TABLE B.4. Programs, strategies, and terms that involve elements of Integrated Corridor Management.

Programs	Elements Supporting ICM
Traffic Incident Management (TIM)	Mobility, travel time reliability, and traveler safety are negatively impacted when traffic incidents occur. TIM programs have made an effort to shift away from traditional ad-hoc incident response towards coordinated incident response while exploring new tools and technologies that can improve incident detection, response and clearance. The overall objectives of TIM programs: 1) responder safety; 2) safe, quick clearance; and 3) prompt, reliable, interoperable communications share common goals with ICM.
Transportation Management Centers (TMCs) and Transportation Operations Centers (TOCs)	TMCs and TOCs are the technical and institutional hub of most freeway and arterial management systems. It is where transportation system data is collected, processed, and synthesized to produce information to be used in decision-making. TMC staff use this information to monitor the operation of the freeway and to initiate control strategies in response to traffic situations and incidents. The various jurisdictions that play a role in TMCs/TOCs share a common goal of optimizing the performance of the entire surface transportation system. Improving decision-support systems in an ICM system often involves the infrastructure and processes that exist at TMCs/TOCs.
Transportation System Management & Operation (TSM&O)	TSM&O strategies optimize the transportation system with management and operation strategies, instead of building high-cost infrastructure projects. With fewer funds available to build our way out of congestion, TSM&O strategies focus on ITS applications. One way to improve ICM is by integrating existing ITS and management efforts into multi-modal, multi-jurisdictional, corridor-wide transportation management systems.
Active Transportation and Demand Management (ATDM)	ATDM is identified in MAP-21 as one of the components of TSM&O. Using available tools and assets, traffic flow is managed and traveler behavior is influenced in real-time to achieve operational objectives. ATDM strategies fall into the overall ICM approach of managing capacity during crashes, non-recurring congestion, or recurring congestion.
Smart Cities	Smart Cities are defined by the FHWA Joint Program Office (JPO) as a “system of interconnected systems, including employment, health care, retail/entertainment, public services, residences, energy distribution, and not least, transportation. This ‘system of systems’ is tied together by information and communication technologies that transmit and process data about all sorts of activities within the city.” ¹ ICM is

Programs	Elements Supporting ICM
	seen as a practical application of a smart cities objective, confined to a corridor instead of citywide.
¹ U.S. DOT ITS JPO, <i>The Smart/Connected City and Its Implications for Connected Transportation</i> , FHWA-JPO-14-148. Available at: https://www.its.dot.gov/itspac/Dec2014/Smart_Connected_City_FINAL_111314.pdf .	

Strategies for Building Trust and Consensus

Successfully facilitating coordination and collaboration among diverse stakeholder groups that may have competing priorities may come in many shapes and forms. There is no exact formula to determine what strategies are needed for building trust and consensus among ICM stakeholders. However, the following best practices were identified for planning and designing smart corridors.¹⁰

Clear Institutional Framework

A strong project requires a defined institutional framework. Once a project manager or champion is defined, a stakeholder's map needs to be designed to determine a clear workflow diagram and communication protocols. Once the main actors are on board and know their role and responsibilities, a multi-jurisdictional project is able to start the planning process.

Common Vision

The project needs to have a common vision across all the stakeholders. An agreement needs to be set on what problems the project will address and which future scenario is expected once the project is up and running. This involves having a stated and written agreement on the project's mission, goals and objectives. It is important to consider possible funds to establish objectives in line with targeted funding programs. For example, if the project is looking to obtain funding from Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grants, the objective should consider improving safety, efficiency, system performance, and infrastructure return on investment.

Secure Funding

One of the most important factors in a successful traffic management project is to have a realistic funding plan. This plan needs to consider important costs throughout the project's life cycle, including operation costs, maintenance, and training, among others.

It is important to determine the funds available for this project and understand the phases that they could be used for. In general, implementation costs require a significant amount of resources. If one of the ICM strategies requires adaptive signal control along alternative arterial routes, all jurisdictions within the ICM corridor need to secure funding for any necessary traffic signal upgrades within the same period in order for the strategy to be feasible. For implementation costs, similar projects have looked at Federal funds like STP, ATCMTD, CMAQ, and ITS funds, which could contribute with a significant share of the necessary funds.

¹⁰ Smart Corridor projects are intended to improve travel for all modes (passenger traffic, freight, and transit) through low-cost solutions and Intelligent Transportation Systems (ITS) along a specified roadway facility. Best practices have been adapted from: Cambridge Systematics, Inc. *Cook DuPage Smart Corridors Plan and Design Report: Technical Report*. 2015.

Equally important is to determine how the day-to-day operation scheme would be funded. Several mechanisms can be considered. Alternatives, such as tax cuts, State and local resources, cooperative and cost-sharing agreements, have been proven successful. Projects of this type can be taken as an opportunity for local agencies—which currently fund their traffic signal operations—to upgrade and implement technology for their cause at a lesser cost than doing it individually. Once a project champion is defined, as well as responsibilities and jurisdictions, a stable financial plan can be thought through to ensure the success of the project.

Arrangements and Agreements

Having clear and precise documents stating roles and responsibilities of different stakeholders is key for success. It is critical that agreements and responsibilities are defined over Memorandums of Understanding (MOUs), cooperative agreements, and official reports, like the Concept of Operations in Kansas City or the Strategic Transportation Plan in Gateway Cities.

Operational Expertise

A successful transportation management system relies heavily on the operability of the project. For this reason, it is important to consider and include staff members or external consultants with a desired level of expertise in the field. This helps reduce the risk of inoperability at early deployment, which might have an important effect during the project lifespan. It is important to consider this not only during the implementation, but also during the day-to-day activities. For this, training should be considered at early phases of the project.

Operational Collaboration

Managing the complexity of an integrated corridor management system (ICMS) implementation will not be easy. In most cases, the project will involve bringing together multiple agencies that perform operations using diverse methods and include the integration of their heterogeneous systems. Increased communication, organization and documentation will be required to ensure that all project partners understand and agree upon project expectations and are kept informed of the status of the project. Systems engineering is the discipline developed to manage the complexity of large-scale systems. In particular, systems engineering is often used in the management of software-intensive projects. It is highly recommended that a systems engineering approach (see FIGURE B.4) be used to manage ICMS implementations. Having a defined process tailored to the ICMS project will be critical for successful implementation.¹¹

As the ICMS is being designed, one example of collaboration that is required of the various operations-level decision makers is the mechanism by which response plans will be selected and implemented. Together, the ICM team develops the business rules for selecting specific response plans, which are coded into the decision support system (DSS). The Dallas U.S.-75 ICM team opted to designate a specific ICM Coordinator whose role would be to evaluate and approve the response plans generated by the DSS before they are sent to all operating agencies. Unlike the Dallas ICMS, the San Diego I-15 ICMS identifies congestion events automatically, using stakeholder-defined thresholds for operational conditions and running them against real-time data. When traffic conditions meet certain thresholds, the DSS takes a combination of appropriate subsystem action plans to form a response plan, which is triggered automatically. Although the San Diego DSS implements response plans without requiring human

¹¹ Federal Highway Administration. *Integrated Corridor Management: Implementation Guide and Lessons Learned*. FHWA-JPO-12-075. February 2012. https://ntl.bts.gov/lib/47000/47600/47670/FHWA-JPO-12-075_FinalPKG_508.pdf

intervention, it does have the ability for a transportation operator to object to the recommended response plan and prevent it from being implemented in their area.

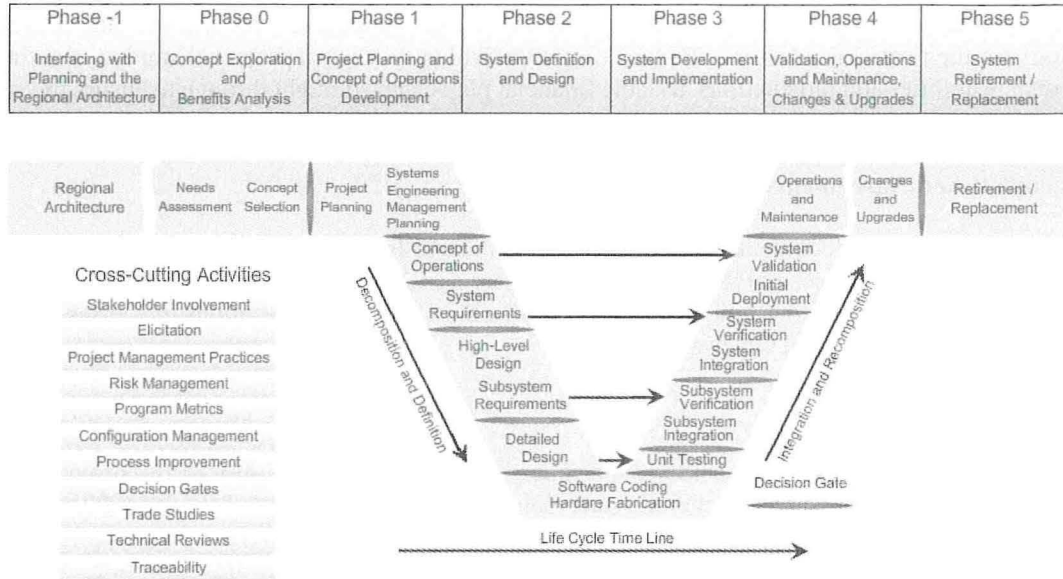


FIGURE B.4. Systems Engineering V-Diagram (U.S. Department of Transportation, Federal Highway Administration, Systems Engineering Guidebook for Intelligent Transportation Systems).

Regular Feedback

Regular feedback is necessary for continuous improvement, one of the critical pieces of FHWA's ICM implementation process. Traffic conditions are in constant flux and the conditions that were assessed at the beginning of an ICM project may have changed before an ICM project has even been fully implemented. This may decrease the effectiveness of implemented response plans. The San Diego I-15 ICM team holds monthly post-incident debriefing meetings with operations-level stakeholders to collect feedback on aspects of the ICMS that work well, and elements that need to be improved.

Stakeholder Interview Participants

A series of stakeholder interviews were conducted with key ICM stakeholders to record their lessons learned from ICM efforts and/or determine their level of interest in ICM. TABLE C.1 lists the candidates approved for inclusion in the stakeholder interviews.

TABLE C.1. List of interview participants.

Name	Stakeholder Perspective	Agency/Position	Outcome
Bill Gardner	Freight	Director of Freight Planning MnDOT	Interviewed on 11-11-2016
Wendy Jia	Transit	Systems and Capital Planning Manager WMATA	Interviewed on 11-16-2016
Andrew Tang	Transit	Principal Planner BART	Interviewed on 11-22-2016
Allen Chen	Incident Response, Freight	Senior Transportation Engineer Caltrans District 7	Interviewed on 11-17-2016
Nick Compin	Incident Response, Freight	Chief—Office of Strategic Development Caltrans District 4	Interviewed on 11-17-2016
Melissa Ackert	Transit	TSM&O Engineer FDOT	Interviewed on 11-18-2016
Susan Catlett	Freight, Bike/Ped, Incident Response	Project Manager New Jersey DOT	Interviewed on 11-22-2016
Mike Marsico	All	Assistant Commissioner New York City DOT	Interviewed on 11-21-2016
Andrew Weeks ¹	All	Director of Modeling and Data Analysis New York City DOT	Interviewed on 11-21-2016
Athena Hutchins	All	Executive Director NITTEC	Interviewed on 11-21-2016
Caroline Mays	Freight	Interim Director of Freight and Int'l Trade TXDOT	Interviewed on 11-17-2016
Blaine Leonard	General	ITS Program Manager UDOT	Interviewed on 11-21-2016
Alex Estrella	General	Senior Transportation Planner SANDAG	Interviewed on 11-22-2016

Name	Stakeholder Perspective	Agency/Position	Outcome
Scott Strelecki ¹	General	Associate Regional Planner SANDAG	Interviewed on 11-22-2016
Elisa Arias ¹	General	Principal Regional Planner SANDAG	Interviewed on 11-22-2016
Christina Casgar	Freight	Goods Movement Policy Manager SANDAG	Interviewed on 11-22-2016
Todd Plesko	Transit	VP of Planning and Development Dallas Area Rapid Transit	Interviewed on 11-21-2016
Chris Poe	General	Assistant Director of C/AV Transportation TTI	Interviewed on 11-15-2016
Ron Achelpohl	All	Planning Director MARC	Interviewed on 11-10-2016
Ray Webb	All	Manager of Traffic Operations MARC	Interviewed on 11-17-2016
Michelle Mowery	Bike/Ped (Public Sector)	Bike Planner LADOT	Interviewed on 11-14-2016
Julia Salinas	Bike/Ped (Public Sector)	Transportation Planning Manager LA Metro	Interviewed on 11-15-2016
Colin Bogart	Bike/Ped (Advocacy Groups)	Education Director LA County Bike Coalition (LACBC)	Interviewed on 11-28-2016
Herbie Huff	Bike/Ped (Advocacy Groups)	Research Associate, UCLA Lewis Center and Board Member of LACBC	Interviewed on 11-22-2016

¹ These interview participants were recommended for inclusion by one of the original 25 invited participants, but were not themselves one of the original 25.

Performance Measure Guidance

*NCHRP Web-Only Document 97: Guide to Effective Freeway Performance Measurement*¹² provides transportation engineers and planners assistance in developing and maintaining a comprehensive freeway performance-monitoring program. Multiple aspects of freeway performance were considered, including congestion, mobility, safety, operational efficiency, ride quality, environmental, and customer satisfaction. This report's guidance can lend itself to ICM projects where freeway congestion is often the driver for these types of project implementations. Adapted from *NCHRP Web-Only Document 97*, TABLE D.1 provides a wide variety of potential performance measures that can be used to evaluate how well an ICM project meets its goals and objectives. The appropriate geographic and temporal scales are listed for each metric.

In the table, "Quality of Service" denotes a more intuitive term for the outcome category of measures, while "Activity-Based" is more apt for the output category of measures. Quality of service (outcome) and activity-based (output) performance measures must be linked together and tied into the mission of the transportation agency.

¹² *NCHRP Web-Only Document 97: Guide to Effective Freeway Performance Measurement: Final Report and Guidebook*, Document 97, 2006.

TABLE D.1. Recommended core freeway performance measures.

Performance Metric	Definition	Units	Geographic Scale	Time Scale
<i>Average (Typical) Congestion Conditions (Quality of Service)</i>				
Travel Time	The average time consumed by vehicles traversing a fixed distance of freeway	Minutes	Specific points on a section or a representative trip only; separately for GP and HOV lanes	Peak hour, a.m./p.m. peak-periods, midday, daily
Travel Time Index	The ratio of the actual travel rate to the ideal travel rate ¹	None; minimum value = 1.000	Section and areawide as a minimum; separately for GP and HOV lanes	Peak hour, a.m./p.m. peak-periods, midday, daily
Total Delay, Vehicles	The excess travel time used on a trip, facility, or freeway segment beyond what would occur under ideal conditions ²	Vehicle-hours	Section and areawide as a minimum; separately for GP and HOV lanes	Peak hour, a.m./p.m. peak-periods, midday, daily
Total Delay, Persons	The excess travel time used on a trip, facility, or freeway segment beyond what would occur under ideal conditions ³	Person-hours	Section and areawide as a minimum; separately for GP and HOV lanes	Peak hour, a.m./p.m. peak-periods, midday, daily
Delay per Vehicle	Total freeway delay divided by the number of vehicles using the freeway	Hours (vehicle-hours per vehicle)	Section and areawide	Peak hour, a.m./p.m. peak-periods; daily
Spatial Extent of Congestion No. 1	Percent of Freeway VMT with Average Section Speeds <50 mph ⁴	Percent	Section and areawide	Peak hour, a.m./p.m. peak-periods
Spatial Extent of Congestion No. 2	Percent of Freeway VMT with Average Section Speeds <30 mph	Percent	Section and areawide	Peak hour, a.m./p.m. peak-periods
Temporal Extent of Congestion No. 1	Percent of Day with Average Freeway Section Speeds <50 mph	Percent	Section and areawide	Daily
Temporal Extent of Congestion No. 2	Percent of Day with Average Freeway Section Speeds <30 mph	Percent	Section and areawide	Daily
Density	Number of vehicles occupying a length of freeway	Vehicles per lane-mile	Section	Peak hour/periods for weekday/weekend
<i>Reliability (Quality of Service)</i>				
Buffer Index	The difference between the 95th percentile travel time and the average travel time, normalized by the average travel time	Percent	Section and areawide	Peak hour, a.m./p.m. peak-periods, midday, daily
Planning Time Index	The 95th Percentile Travel Time Index	None; minimum value = 1.000	Section and areawide	Peak hour, a.m./p.m. peak-periods, midday, daily

TABLE D.1. Recommended core freeway performance measures (continued).

Performance Metric	Definition	Units	Geographic Scale	Time Scale
<i>Capacity Bottlenecks (Activity-Based)</i>				
Geometric Deficiencies Related to Traffic Flow (Potential Bottlenecks)	Count of potential bottleneck locations by type ⁵	Number	Section and areawide	N/A
Major Traffic-Influencing Bottlenecks	Count of locations that are the primary cause of traffic flow breakdown on a highway section, by type	Number	Section and areawide	N/A
<i>Throughput (Quality of Service)</i>				
Throughput—Vehicle	Number of vehicles traversing a freeway	Vehicles per unit time	Section and areawide	Peak hour, a.m./p.m. peak-periods, midday, daily
Throughput—Persons	Number of persons traversing a freeway	Persons per unit time	Section and areawide	Peak hour, a.m./p.m. peak-periods, midday, daily
Vehicle-Miles of Travel	The product of the number of vehicles traveling over a length of freeway, times the length of the freeway	Vehicle-miles	Section and areawide	Peak hour, a.m./p.m. peak-periods, midday, daily
Truck Vehicle-Miles of Travel	The product of the number of trucks traveling over a length of freeway, ⁶ times the length of the freeway	Vehicle-miles	Section and areawide	Peak hour, a.m./p.m. peak-periods, midday, daily
Lost Highway Productivity	Lost capacity due to flow breakdown—the difference between measured volumes on a freeway segment under congested flow versus the maximum capacity for that segment	Vehicles per hour	Section and areawide	Peak hour, a.m./p.m. peak-periods, midday, daily
<i>Customer Satisfaction (Quality of Service)</i>				
Worst Aspect of Freeway Congestion	(Defined by question)	1) happens every work day; 2) incidents that are not cleared in time; and 3) encountering work zones	Areawide or statewide	Annually; tied to survey frequency
Satisfaction with Time to Make Long-Distance Trips Using Freeways	(Defined by question)	1) very satisfied; 2) somewhat satisfied; 3) neutral; 4) somewhat dissatisfied; 5) very dissatisfied; and 6) do not know	Areawide or statewide	Annually; tied to survey frequency

TABLE D.1. Recommended core freeway performance measures (continued).

Performance Metric	Definition	Units	Geographic Scale	Time Scale
<i>Safety (Quality of Service)</i>				
Total Crashes	Freeway crashes as defined by the State, i.e., those for which a police accident report form is generated	Number	All safety measures computed areawide; section level may be computed if multiple years are used	All safety measures computed annually
Fatal Crashes	Freeway crashes as defined by the State, i.e., those for which a police accident report form is generated, where at least one fatality occurred	Number	All safety measures computed areawide; section level may be computed if multiple years are used	All safety measures computed annually
Overall Crash Rate	Total freeway crashes divided by freeway VMT for the time period considered	Number per 100 million vehicle-miles	All safety measures computed areawide; section level may be computed if multiple years are used	All safety measures computed annually
Fatality Crash Rate	Total freeway fatal crashes divided by freeway VMT for the time period considered	Number per 100 million vehicle-miles	All safety measures computed areawide; section level may be computed if multiple years are used	All safety measures computed annually
Secondary Crashes	A police-reported crash that occurs in the presence of an earlier crash ⁷	Number	All safety measures computed areawide; section level may be computed if multiple years are used	All safety measures computed annually
<i>Ride Quality (Quality of Service)</i>				
Present Serviceability Rating (PSR)	The general indicator of ride quality on pavement surfaces ⁸	(Internal scale)	Section and areawide	Annually
International Roughness Index (IRI)	Cumulative deviation from a smooth surface	Inches per mile	Section and areawide	Annually
<i>Environment (Quality of Service)</i>				
Nitrous Oxides (NO _x) Emission Rate	Modeled NO _x attributable to freeways divided by freeway VMT	Number	Section and areawide	Annually
Volatile Organic Compound (VOC) Emission Rate	Modeled VOC attributable to freeways divided by freeway VMT	Number	Section and areawide	Annually
Carbon Monoxide (CO) Emission Rate	Modeled CO attributable to freeways divided by freeway VMT	Number	Section and areawide	Annually
Fuel Consumption per VMT	Modeled gallons of fuel consumed on a freeway divided by freeway VMT	Number	Section and areawide	Annually

TABLE D.1. Recommended core freeway performance measures (continued).

Performance Metric	Definition	Units	Geographic Scale	Time Scale
<i>Incident Characteristics (Activity-Based)</i>				
No. of Incidents by Type and Extent of Blockage	Self-explanatory	Type: 1) crash; 2) vehicle breakdown; 3) spill; and 4) other. Blockage: Actual number of lanes blocked; separate code for shoulder blockage	Section and areawide	a.m./p.m. peak-periods, daily
Incident Duration ⁹	The time elapsed from the notification of an incident to when the last responder has left the incident scene	Minutes (median)	Section and areawide	a.m./p.m. peak-periods, daily
Blockage Duration	The time elapsed from the notification of an incident to when all evidence of the incident (including responders' vehicles) has been removed from the travel lanes	Minutes (median)	Section and areawide	a.m./p.m. peak-periods, daily
Lane-Hours Loss Due to Incidents	The number of whole or partial freeway lanes blocked by the incident and its responders, multiplied by the number of hours the lanes are blocked	Lane-hours	Section and areawide	a.m./p.m. peak-periods, daily
<i>Work Zones (Activity-Based)</i>				
No. of Work Zones by Type of Activity	The underlying reason why the work zone was initiated: 1) resurfacing only; 2) RRR; 3) lane addition w/o interchanges; 4) lane additions w/interchanges; 5) minor cross-section; 6) grade flattening; 7) curve flattening; 8) bridge deck; 9) bridge superstructure; 10) bridge replacement; and 11) sign related	Number	Section and areawide	Daily
Lane-Hours Lost Due to Work Zones	The number of whole or partial freeway lanes blocked by the work zone, multiplied by the number of hours the lanes are blocked	Lane-hours	Section and areawide	a.m./p.m. peak-periods; midday; night; daily
Average Work Zone Duration by Type of Activity	The elapsed time that work zone activities are in effect	Hours	Section and areawide	Daily
Lane-Miles Lost Due to Work Zones	The number of whole or partial freeway lanes blocked by the work zone, multiplied by the length of the work zone	Lane-miles	Section and areawide	a.m./p.m. peak-periods, daily

TABLE D.1. Recommended core freeway performance measures (continued).

Performance Metric	Definition	Units	Geographic Scale	Time Scale
<i>Weather (Activity-Based)</i>				
Extent of highways affected by snow or ice	Highway centerline mileage under the influence of uncleared snow or ice multiplied by the length of time of the influence	Centerline-Mile-Hours	Section and areawide	Daily
Extent of highways affected by rain	Highway centerline mileage under the influence of rain multiplied by the length of time of the influence	Centerline-Mile-Hours	Section and areawide	Daily
Extent of highways affected by fog	Highway centerline mileage under the influence of fog multiplied by the length of time of the influence	Centerline-Mile-Hours	Section and areawide	Daily
<i>Operational Efficiency (Activity-Based)</i>				
Percent Freeway Directional Miles with traffic sensors, surveillance cameras, DMS, service patrol coverage	One measure for each type of equipment deployed in an area	Percentage (xxx.x%)	Section and areawide	Annually
Percent of Equipment (DMS, surveillance cameras, traffic sensors, ramp meters, RWIS) in "Good" or Better Condition	One measure for each type of equipment deployed in an area	Percentage (xxx.x%)	Section and areawide	Annually
Percent of total device-days out-of-service (by type of device)	One measure for each type of equipment deployed in an area	Percentage (xxx.x%)	Section and areawide	Annually
Service patrol assists	Self-explanatory	Number	Section and areawide	Annually

Source: NCHRP, Guide to Effective Freeway Performance Measurement: Final Report and Guidebook, Document 97, 2006.

¹ Travel rate is the inverse of speed, measured in minutes per mile. The "ideal travel rate" is the rate that occurs at the free-flow speed of a facility, or a fixed value set for all facilities that is meant to indicate ideal conditions or "unconstrained" (see text for discussion of the ideal/unconstrained/free-flow speed).

² See text above for definition of "ideal."

³ See text above for definition of "ideal."

⁴ A freeway "section" is the length of freeway that represents a relatively homogenous trip by users. Logical break points are major interchanges (especially freeway-to-freeway) and destinations (e.g., Central Business District). The term "section" is sometimes used to describe this, but it usually implies additional parallel freeways and/or transit routes.

⁵ Bottleneck types are: Types A-C weaving areas (see HCM, Section 7.0); left exits; freeway-to-freeway merge areas; surface street on-ramp merge areas; acceleration lanes at merge areas <300 feet; lane drops; lane width drops ≥ 1 foot; directional miles with left shoulders <6 feet; directional miles with right shoulders <6 feet; steep grades; substandard horizontal curves. The shoulder categories are included because of the ability of more than 6-foot shoulders to shelter vehicles during traffic incidents.

⁶ Trucks are defined as vehicles with at least six tires, i.e., FHWA Classes 5 through 13 plus any larger vehicles as defined by a state.

⁷ See report text for discussion.

⁸ See: http://www.fhwa.dot.gov/policy/1999cpr/ch_03/cpg03_2.htm.

⁹ Since in many cases the actual time the incident occurred is unknown, the notification time is used to indicate the official "start" of the incident. On most urban freeways, with use of cell phones by the public, the time between when the incident occurs and when it is first reported is very small.

Once the necessary data are collected and key performance metrics have been calculated, it is recommended that the results be tested for statistical significance. This helps to determine whether the changes observed (e.g., increase or decrease in travel times, speeds, throughput) are “real,” or whether they are simply due to chance. TABLE D.2 provides several examples of relevant statistical tests to use for a variety of performance metrics, while TABLE D.3 provides additional detail on the test themselves.

TABLE D.2. Performance measures and statistical tests.

Performance Metric	Relevant Tests for Evaluating Statistical Significance
Vehicle-hours of delay	Mann-Whitney U Test or Wald Test
Corridor travel times	Mann-Whitney U Test (Wilcoxon Rank Sum Test)
Carpool rates	Chi-Square Test
Vehicle throughput	Student’s Two-Sample (Unpaired) <i>t</i> test
Percent of time that speed > 45 mph ¹	Fisher’s Test
HOV violation rates	Student’s Two-Sample (Unpaired) <i>t</i> test

¹The federal performance standard for Express Lanes requires the facility to meet a minimum average operating speed of 45 mph for 90 percent of the time.

These are several guidelines regarding distributions of traffic-related data:

- Traffic crash counts follow Poisson distributions.¹³
- Queue lengths and delays vary depending on operating conditions (e.g., the reason for the queue) and traffic arrivals (e.g., platoons, Poisson).
- Travel times on arterials may follow an overly complex distribution.¹⁴
- Travel times in general are challenging to characterize by a parameterized distribution, though there is limited evidence for Lognormal or Gamma distributions.¹⁵ ¹⁶ Gamma distributions can be summed to result in a new Gamma distribution; Lognormal distributions do not have this property.
- Bottleneck discharge, when considered as an average for the full time the bottleneck is active from day to day, follows a normal distribution.¹⁷

¹³ Wasserman. Page 119.

¹⁴ Bayen. Probability distributions of travel times on arterial networks: a traffic flow and horizontal queuing theory approach. http://bayen.eecs.berkeley.edu/sites/default/files/conferences/TRB2012_stat_traffic.pdf

¹⁵ Wu. Standard Deviation of Travel Time in a Freeway Network – a Mathematical Quantifying Tool for Reliability Analysis. https://www.researchgate.net/profile/Ning_Wu7/publication/264690319_Standard_Deviation_of_Travel_Time_in_a_Freeway_Network_a_Mathematical_Quantifying_Tool_for_Reliability_Analysis/links/53eb62a70cf2593ba7087b33.pdf.

¹⁶ Li, Chai, Tang. Empirical Study of Travel Time Estimation and Reliability. <http://www.hindawi.com/journals/mpe/2013/504579/>.

¹⁷ Zhang and Levinson. Some Properties of Flows at Freeway Bottlenecks. <https://wiki.cecs.pdx.edu/pub/Main/SirishaKothuri/Zhang.pdf>.

TABLE D.3. Statistical tests for comparison.

Statistical Test	Description	Assumptions	Applications	Comments
Wilcoxon Rank-Sum (or Mann-Whitney U) Test	Used as an alternative to the two-sample t -test without the assumption of normally distributed data.	<ul style="list-style-type: none"> • Data can be ordered. • Data distribution of each sample has same shape and variance.² 	<ul style="list-style-type: none"> • Tests whether the medians (not the means) of two independent samples are equal. 	<ul style="list-style-type: none"> • The Median Test is another, less powerful non-parametric test alternative to this.
Wald Test ³	Used to compare two estimates for a distribution scalar parameter (e.g., mean, median).	<ul style="list-style-type: none"> • The estimate for the scalar parameter is asymptotically normal (e.g., mean, median). 	<ul style="list-style-type: none"> • Can be used to test whether two samples have the same mean, without making assumptions about the sample distributions. • Can be used to test whether two samples have the same median, without making assumptions about the sample distributions. Requires estimating standard error using bootstrap. 	<ul style="list-style-type: none"> • The Likelihood Ratio Test is another similar method with greater flexibility.
Chi-Square Test ⁴	Measures how well the observed distribution of data fits with the distribution that is expected if the variables are independent.	<ul style="list-style-type: none"> • Datasets are large enough. • Data is not correlated. 	<ul style="list-style-type: none"> • Can be used to test how likely it is that an observed distribution is due to chance. It is called a “goodness of fit” statistic. 	<ul style="list-style-type: none"> • Fisher’s test may be more appropriate when sample sizes are small.

TABLE D.3. Statistical tests for comparison (continued).

Statistical Test	Description	Assumptions	Applications	Comments
Student's Two-Sample Test ⁵	Used to determine if two population means are equal.	<ul style="list-style-type: none"> Data may be paired or unpaired. The variances of two samples may be assumed to be equal or unequal. 	<ul style="list-style-type: none"> Testing if a process or treatment is equivalent to another process or treatment. Testing if a new process or treatment is superior to a current process or treatment. Testing if a new process or treatment is superior to a current process or treatment by at least some predetermined threshold amount. 	<ul style="list-style-type: none"> When the paired data does not have normally distributed differences, use the Wilcoxon Signed-Rank Test.
Fisher's Test ^{6,7}	Used to test whether one categorical variable is independent from another categorical variable.	<ul style="list-style-type: none"> Assumes row and column totals in the contingency table are known in advance. This is generally not the case for the outcome totals (e.g., the total number of travelers that will arrive on time is not known in advance). When this assumption is violated, the test becomes <i>more conservative</i>. 	<ul style="list-style-type: none"> Testing a treatment (i.e., the first categorical variable is with/without treatment) and evaluating a categorical outcome (e.g., traveler arrives on time or not). There can be more than two categorical outcomes (e.g., different service rating classifications). 	<ul style="list-style-type: none"> When the sample size is larger than 1,000, the Pearson's Chi-Squared test is recommended instead. If using a Pearson's Chi-Squared Test, ensure no expected value is less than 5. For paired testing, use McNemar's test.

¹ <http://www.mathworks.com/help/stats/ranksum.html#bti4z5t>.² <http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/hypothesis-tests/nonparametrics-tests/which-test-should-i-use/#choosing-between-the-two-sample-mann-whitney-test-and-the-pooled-t-test>.³ Wasserman.⁴ <http://www.ling.upenn.edu/~clight/chisquared.htm>.⁵ <http://www.itl.nist.gov/div898/handbook/eda/section3/eda353.htm>.⁶ <http://www.biostat handbook.com/fishers.html>.⁷ Weisstein, Eric W. "Fisher's Exact Test." From MathWorld--A Wolfram Web Resource. <http://mathworld.wolfram.com/FishersExactTest.html>.



APPENDIX E

Analysis Methodology, Tools, and Plan

As part of the Federal Highway Administration (FHWA) Traffic Analysis Toolbox (Volume XIII), the Integrated Corridor Management Analysis, Modeling, and Simulation Guide¹⁸ (updated in 2017) was designed to help corridor stakeholders implement the ICM Analysis, Modeling, and Simulation (AMS) methodology successfully and effectively. This appendix condenses the main points, namely, the value, approach, challenges, and resources required of each of the five work steps included in the AMS Guide. For more in-depth details on this methodology, please refer to FHWA's full report.

Introduction to Integrated Corridor Management Analysis, Modeling, and Simulation

The ICM initiative developed an AMS methodology to assist corridor managers in forecasting and assessing the potential benefits and implications of ICM in their corridors of interest. The ICM AMS Guide has been incorporated into the Federal Highway Administration (FHWA) Traffic Analysis Toolbox (Volume XIII) and Traffic Simulation Guidelines (Please visit the FHWA Traffic Analysis Toolbox web page for more information: <http://www.ops.fhwa.dot.gov/trafficanalysistools/index.htm>). Unlike traditional corridor studies, which often focus on a specific element of a corridor (i.e., a freeway or freeway and frontage road during a specific time of day), ICM AMS is a comprehensive approach that analyzes different operational conditions across time and modes and across a large enough geographic area to absorb all impacts.

The complexity involved in this type of analysis goes far beyond what is typically required for more traditional types of transportation investments. The potential inclusion of multiple facility types (freeway and arterial) and multiple transportation modes, combined with the potential for road use pricing influences, complicates the analysis. The focus of the ICM strategies on non-typical operational scenarios (e.g., high demand, incidents, and inclement weather) adds further complexity to the assessment. Finally, the ICM AMS methodology enables a more sensitive analysis of corridor-level performance. Traditional travel demand models are sufficient for analyzing the impacts of major infrastructure investments, such as new freeways. However, when agencies are interested in fine-tuning transportation operations strategies to produce system-wide improvements that optimize existing infrastructure performance, they need time- and space-dynamic tools that are more sensitive and that enable insight into the benefits that are otherwise too marginal to see in traditional modeling. The ICM AMS approach is neither inexpensive nor easy to accomplish. However, the value gained outweighs the expense and pays dividends throughout an ICM Initiative by reducing the chance of very expensive missteps in implementation; streamlining the implementation process; and allowing corridor stakeholders to deploy ICM AMS more rapidly and at a lower cost, given the lessons learned in this effort.

¹⁸ FHWA, Traffic Analysis Toolbox Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide, FHWA-JPO-16-397, February 2017.

One of the defining features of the ICM AMS methodology is that it enables agencies to understand system dynamics at the corridor level. The ICM AMS methodology uses corridor-level performance metrics in addition to facility-level metrics to evaluate and understand corridor performance. The ICM AMS methodology accomplishes this through the combined use of multiple classes of available modeling tools. By combining aspects of macroscopic simulation (i.e., travel demand modeling (TDM), good for analyzing implications associated with mode shift), mesoscopic simulation (utilized to analyze regional strategies such as traveler information and pricing), and microscopic simulation (ideal for analyzing traffic control strategies), the ICM AMS methodology enables robust hypothesis modeling under a range of operating conditions of interest to the corridor for more informed decision-making. This produces improved analysis as compared to travel demand models alone because the combined tools yield more accurate travel times and speeds through the corridor, more in-depth understanding of bottleneck locations and their root causes, and an understanding of the influences beyond the periphery of the corridor that underlie corridor demand. The use of the different models allows specific strengths of the individual models to be combined: travel demand models provide estimates of long-term travel demand changes resulting from capacity changes or pricing strategies, while more focused meso- and microsimulation models assess short-term operational impacts during specific non-recurring congestion conditions.

The AMS approach is intended to be a flexible and iterative process adaptable to a wide variety of conditions, strategies, and situations. This flexibility is intended to provide practitioners with sufficient structure to enable a rigorous analysis suitable to complex strategies that at the same time is not so rigid as to limit the ability to restructure and rerun the analysis to address project contingencies as they occur. The AMS approach is designed to be implemented in conjunction with the ICM system development and design process (the ICM implementation process follows the systems engineering life-cycle process), and to provide a tool for continuous improvement of corridor performance. Regular periodic conduct of ICM AMS also supports continuous improvement of the supporting ICM system, and the models themselves.

As the AMS process continues in parallel with the ICM system development and design process, it is likely that new strategies, alternatives and scenarios will emerge that will need to be evaluated within the AMS process; therefore, the flexibility to foresee and account for several iterations of analysis is critical. The design process may reveal new strategies or alternatives that may need to be analyzed in the AMS, prompting modifications to the AMS structure. Likewise, the AMS process may reveal parts of the concept of operations that are unworkable or uncover opportunities that may be leveraged that result in changes to the ultimate ICM design.

The advanced analysis capabilities of the AMS approach provide practitioners with enhanced opportunities to conduct detailed alternatives analysis to identify optimal combinations of strategies and to test and refine how the strategies may be most optimally implemented. Due to the complexity and resources required of the AMS, this level of analysis is typically most appropriate in the later planning stages after the preliminary screening of alternatives has winnowed out a smaller set of strategies and alternatives to be evaluated. The AMS will often continue through the design phase—being used to fine-tune strategies in an iterative function as the realities of the design process progress or to assess the impacts of sequencing the improvements to identify the optimal deployment phasing of the strategies.

However, these greatly expanded analysis capabilities come at a cost. The AMS approach is demanding in terms of data needs, staff skill levels, and the amount of time and resources that need to be devoted to implement and conduct the analysis successfully. Practitioners should not underestimate these requirements. Caveats to practitioners include:

- Significant data are needed to conduct the analysis. These data need to be high quality, reliable, and provide continuous coverage over long periods of time (minimum of six to 12 months) to be of use to the AMS process. If data fitting the requirements of the AMS are not readily available, the costs and

resources necessary to conduct the analysis may need to be expanded in order to collect and analyze the necessary data. Using poor-quality or insufficient data will produce inaccurate results that may lead to poor investment decisions. These data requirements have become less of an issue with the advent of private-sector data sources based on information provided by smart phones and in-vehicle GPS devices; travel times, travel speeds, and even origin-destination information can now be obtained inexpensively from private-sector data sources. Traffic volumes however are still needed at many locations in the analysis network.

- Staff skill levels must be suitable to the challenge. The complexity of not only using advanced travel demand models and simulation models independently, but also integrating and calibrating these multi-resolution models is challenging even to many advanced users. Agencies with only cursory or even intermediate skills in any one of the modeling platforms should plan either to add budget for staff training or to acquire consultant services to meet these needs.
- Even if data are available and staff skills are robust, the cost of compiling and analyzing the baseline data, developing the analysis framework, calibrating the tools, and completing the analysis is significant and should only be undertaken in situations where the risk of making a poor investment decision outweigh the costs.

Successfully completing the AMS process for an ICM or other strategy analysis is neither inexpensive nor trivial; however, the potential cost savings from avoiding wrongly focused deployments based on inadequate analysis, along with the maximization of potential ICM system benefits through the optimization of the strategies can result in a substantial payback on the investment in AMS. For the Pioneer and Demonstration Sites, the costs of developing and conducting the AMS accounted for approximately five percent of the overall deployment budget. The AMS costs for the Pioneer and Demonstration Sites were likely proportionately higher than they would be in future analysis, due to the need to develop and refine new analysis methods and procedures. Hopefully, the best practices from this development procedure, highlighted in this AMS Guide, can be leveraged by subsequent practitioners to reduce the costs of conducting these activities. If the analysis was successful in better structuring the deployment to increase the efficiency of the ICM by a minimum of five percent, or reduced the risk of a deployment cost overrun of five percent or more, the investment in AMS paid for itself. The partners at the Pioneer Sites felt there was significant value in AMS, which greatly outweighed the analysis costs.

Recommended Integrated Corridor Management Analysis, Modeling, and Simulation Approach

FIGURE E.1 presents the five major work steps, summarized below, associated with implementing the Integrated ICM AMS methodology. This figure will be repeated throughout this appendix as a roadmap through the work steps. These work steps are based upon a nine-step process developed for the FHWA *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*. Although the work steps are consistent, they are not identical.

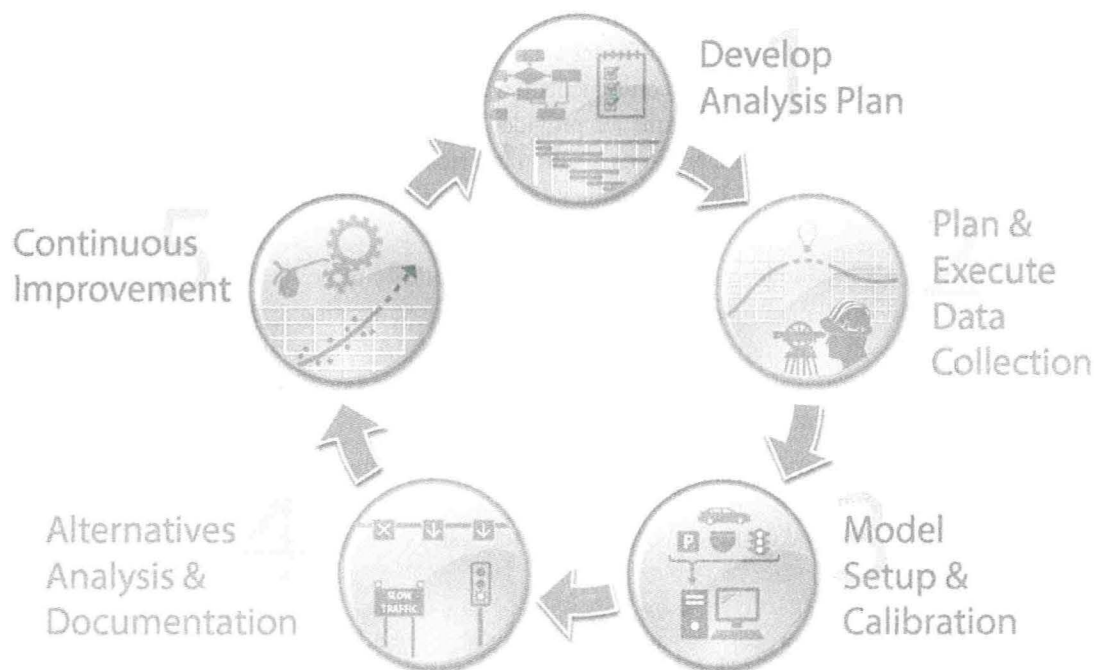


FIGURE E.1. Integrated Corridor Management Analysis, Modeling, and Simulation approach work steps (Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc., 2017).

The five ICM AMS work steps are as follows:

1. Develop Analysis Plan

The analysis plans developed as part of the ICM AMS methodology provide a valuable tool for communicating the scope of the project—a critical element—indeed, the foundation—of success in an AMS project. A team can expect to spend approximately 15 percent of the AMS time investment on this step, which includes initial planning and scoping and then iterative updates to assumptions, scope, and agreements as the project moves forward. The development of the analysis plans is the primary mechanism for securing a clear and mutual understanding among stakeholders of expectations and assumptions. It may help to identify flaws or technical issues in the ICM Concept of Operations (CONOPS) that may have been otherwise overlooked.

Value. The analysis plan confirms not only the stakeholder agreements regarding the scope of the ICM analysis, but also the most appropriate approach to the analysis based on an enhanced understanding of project objectives, the corridor conditions, the ICM strategies being implemented, and the available tools and data. The benefits of completing this work step include a better allocation of resources appropriate to the study objectives; a clear and shared understanding of roles, responsibilities, and expectations among project participants; and the ability of project participants to communicate the project vision effectively to the broader stakeholders. It also helps maintain agreement and project continuity as stakeholders leave positions and new staff comes in mid-stream.

Approach. FIGURE E.2 presents an overview of the substeps related to the development of an analysis plan. The output resulting from completion of each substep maps directly to the development of the analysis plan (see example outline shown in TABLE E.1). The reader is encouraged to review the analysis plans of the three Pioneer Sites and the two Demonstration Sites as references.

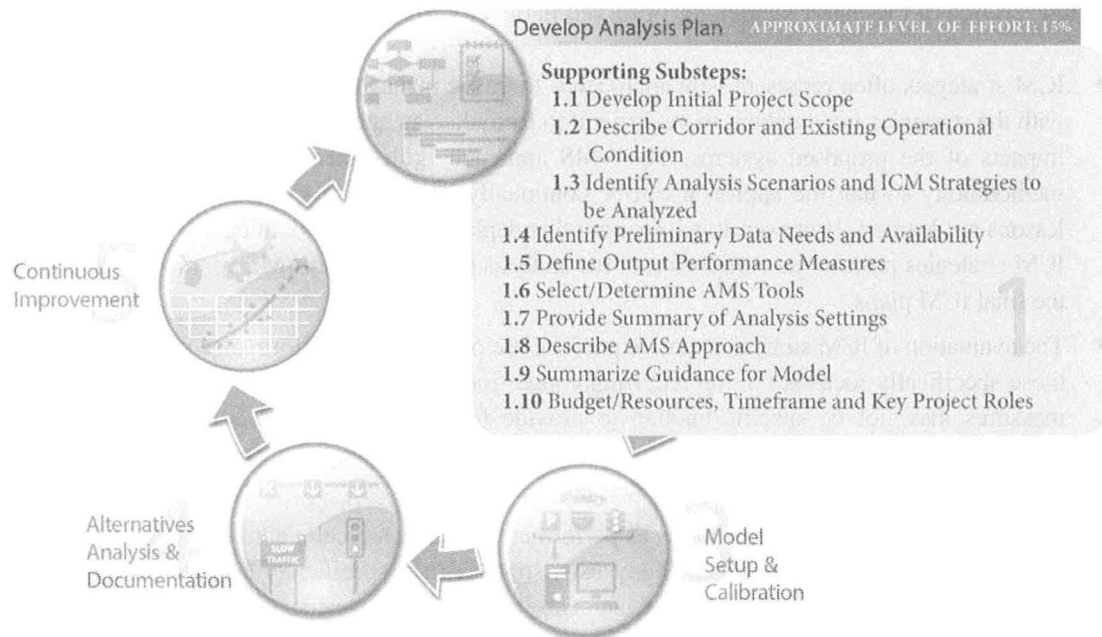


FIGURE E.2. Overview of Workstep 1: Develop Analysis Plan (Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc.).

TABLE E.1. Example outline for Analysis Plan.

Example Analysis Plan Outline

1. Introduction and Initial Project Scope:
 - a. Corridor Overview
 - b. Project Background and Guiding Principles
 - c. Project Goals and Objectives
 - d. Process for Developing and Applying the Analysis Plan
2. Corridor Description and Existing Operational Conditions
3. Analysis Scenarios and ICM Strategies
4. Data Needs and Availability
5. Output Performance Measures
6. AMS Tools and Selection Methodology
7. Summary of Analysis Settings
8. Summary of AMS Approach
9. Guidance for Model Calibration
10. Budget, Schedule and Key Responsibilities
 - a. Budget/Resources
 - a. Schedule/Timeframe
 - a. Key Project Roles/Responsibilities

Source: Cambridge Systematics, Inc., 2012.

Challenges. Some of the major challenges observed in developing the analysis plan are listed below.

- ICM strategies often represent new approaches to traffic management in many regions. Unfamiliarity with the strategies may make it more difficult to formulate an analysis approach and identify the likely impacts of the proposed systems. The AMS approach is designed to promote a flexible analysis methodology so that the approach can be continually improved as more information is gained and lessons are learned. However, it is important that deploying agencies define and refine their proposed ICM strategies prior to the completion of the analysis plan so that the AMS approach is appropriate to the final ICM plans.
- The evaluation of ICM strategies may require the use of unfamiliar performance measures, particularly those specifically focused on non-recurring congestion impacts. In other cases, existing performance measures may not be specific enough to provide for meaningful ICM analysis. Therefore, some additional education may be necessary on the part of AMS managers to inform stakeholders on the importance of these new performance measures.
- Analysis of “average day” conditions as performed for many typical planning efforts is not sufficient for analysis of ICM deployments. Many ICM strategies are specifically targeted at mitigating non-typical events (e.g., high travel demand, incidents, and inclement weather). Therefore, the analysis must be expanded beyond the “typical day” to measure the potential benefits of ICM properly. Cluster analysis is recommended to identify different operational conditions in the corridor, as well as the frequency of occurrence of these conditions. The most impactful clusters of operational conditions will be analyzed using the AMS tools, and then compared to the “do nothing” alternatives representing the transportation system without ICM turned on (but with pre-ICM corridor management practices in-place). The FHWA’s Traffic Analysis Tools Volume III forthcoming update provides a deeper exploration of understanding why this is critical and provides systematic methods (like cluster analysis) of identifying and modeling a representative range of operational conditions.
- The USDOT has provided useful guidance on selecting appropriate analysis tools as part of the Traffic Analysis Tools initiative. However, this guidance is intended to steer practitioners to the appropriate general category of analysis tool and model packages, not to specific software vendors. AMS managers should carefully investigate the capabilities of options within the selected category to identify the most appropriate tools and models. In conducting this assessment, AMS managers should seek out guidance from peers who may have conducted similar analysis or used some of the tools under consideration. Further, when selecting and evaluating software, practitioners should keep in mind that software vendors are continuously updating their packages to meet unmet needs and identified deficiencies. What was the best last year may not be as productive this year. Particularly when dealing with ICM, many new advances are in process, so it is helpful to contact vendors to obtain the latest information.

Resources. Program managers can expect to allocate approximately 15 percent of the project budget to this step of the initiative. This investment pays dividends in accurately scoping and shaping the AMS effort to achieve the desired objectives, including design of the AMS approach to support longer-term analysis of ICM strategies and corridor performance as the corridor and its needs change. This investment can also support enhanced transportation planning, real-time decision support capabilities, and analysis needs of other related initiatives (i.e., active transportation and demand management or ATDM, etc.).

This work step will require the involvement of the full suite of representative stakeholders in ICM from State, regional, and local transportation and planning agencies across the full range of roles, including

freeway, arterial, and transit program and technical managers, engineers, and analysts; transportation planners; and technical modeling and simulation experts.

2. Develop Data Collection Plan and Collect Data

The purpose of this work step is to collect the needed data to support the desired analysis cost effectively. In this step, project partners research data needs and availability, identify available data as well as gaps and methods to address those gaps where possible, compile and archive needed data, collect data, and perform quality control on the collected data. This step represents approximately 15 percent of the total work effort for the AMS initiative.

Value. The value of successfully completing this work step will be the compilation of relevant and useful datasets and metadata necessary to develop the enhanced models and analysis to be utilized in the subsequent steps, and to provide the foundation for continuous process improvement. The data collection plan will help to ensure that the data collected is of sufficient quality for the needs of the study and will guide the partners in collecting the data using methods that minimize the expenditure of resources on this task.

Approach. FIGURE E.3 presents an overview of the substeps related to the development and implementation of the Data Collection Plan. The output from these substeps maps directly to completion of the Data Collection Plan (see FIGURE E.4, Example outline for Data Collection Plan). Subsequent discussions provide additional detail on the recommended conduct of the identified subtasks.

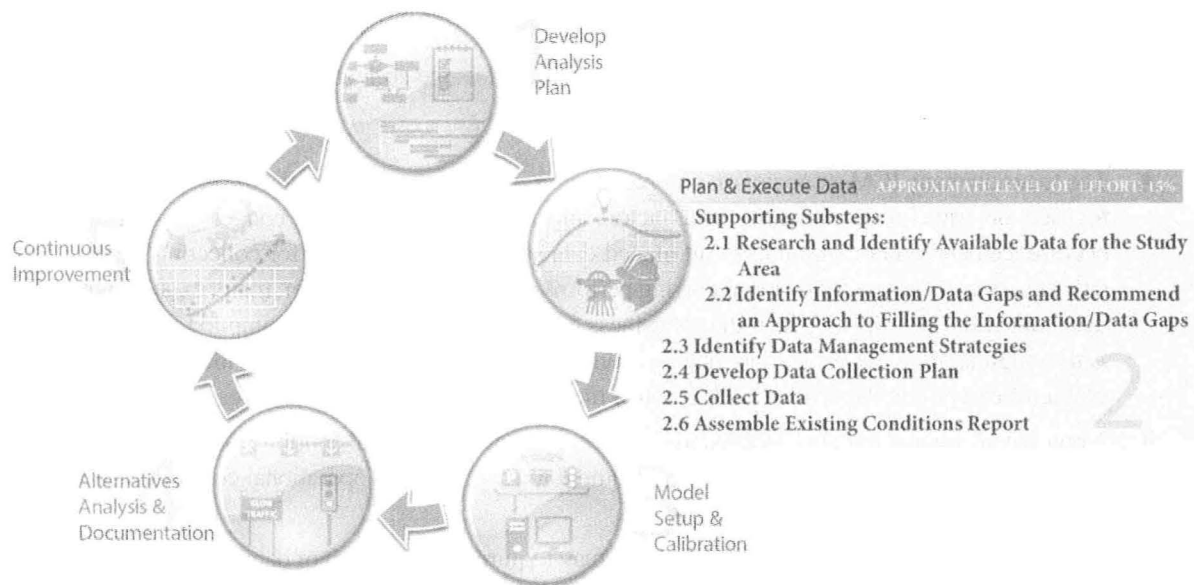


FIGURE E.3. Overview of Workstep 2: Develop Data Collection Plan and Collect Data (Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc.).

Example Data Collection Plan Outline	
1.	Introduction and Background
2.	Data Collection Methodology
3.	Documentation Review
4.	Summary of Input Data for AMS
5.	Summary of Data Requirements for Approaches and Strategies
6.	Current State of Required Data and Gap Identification
6.1	Arterial-Related Data
6.2	Freeway-Related Data
6.3	Transit-Related Data
7.	Summary of Data Collection Methods

FIGURE E.4. Example outline for Data Collection Plan (Cambridge Systematics, Inc., 2012).

The earlier scoping work for the analysis plan can be used to complete Section 1 of the data collection plan (“Introduction and Background”). Similar to the development of the analysis plan, it is likely that in the course of investigating and collecting the data, opportunities and challenges will be encountered that result in modifications to the data requirements and data collection plan. The data collection plan should remain sufficiently flexible so that lessons learned in the compilation of data sources may be adapted and incorporated as part of the continuous improvement of the AMS effort.

Challenges. Due to the innovative nature of many ICM strategies, the collection of relevant data to support AMS offers several unique challenges:

- The focus on many ICM strategies on non-recurring congestion may require the development of datasets focused on travel-time reliability and factors influencing non-recurring congestion (e.g., incident occurrence or weather conditions). Automated data sources are often best for collecting the long-term data necessary to assess these non-recurring performance measures; however, many existing automated data collection systems may lack the robustness or reliability to effectively compile relevant data sets. A thorough assessment of the data quality from all sources is recommended to identify any potential problems early on in the process and establish methods to address any deficiencies.
- A non-trivial amount of data is needed to represent multiple operational conditions and conduct a cluster analysis. Six to 12 months of data may be required to map different operational conditions adequately including incidents, work zones, weather, etc.
- Performance measures necessary for the AMS may require the collection of datasets that are unfamiliar to the managing agency. The AMS manager should seek out peer information on collecting this data for all new or unfamiliar data requirements.
- Data for AMS is required to be collected concurrently—collected for the same dates and times across all modes and facilities. This is often different from typical planning data collection efforts that are assembled from data compiled from different dates and times. The demands for concurrent data can require additional effort to coordinate and synchronize the multiple data collection efforts.
- Data quality from automated data sources (e.g., roadway loop detectors) may sometimes be insufficient for modeling purposes. Sample datasets should be obtained early in the data collection process and analyzed to assess data quality. The data collection plan should specify data quality procedures and minimal data quality requirements for this purpose. Further, AMS managers should discuss any data

quality issues with operations personnel familiar with the data source during the development of the data collection plan in order to understand and anticipate any problems with data source reliability, data accuracy or other condition specific issues (e.g., inaccurate speeds recorded during high volume periods).

- Revealed traveler preferences as they relate to **traveler** responses to incidents in the presence or absence of ICM are presented in the May 2016 report titled “*Integrated Corridor Management Initiative: Overview of the Dallas Traveler Response Panel Survey.*” This report presents findings from the ICM traveler behavior surveys, a set of panel surveys of ICM Demonstration Site corridor users, conducted before and after the deployment of ICM.
- It is critical that the datasets be archived and maintained, along with all data dictionaries and supporting information, according to the data maintenance plans defined in the data collection plan. Failure to do so can result in a loss of data and the loss of resource investment in the data collection task.

Resources. Program managers can expect to allocate approximately 15 percent of the project budget to data collection. This investment pays dividends by creating or updating the corridor’s inventory of available data, which provides a foundation for continual process improvement. This work step may take more or less time based on the state and availability of relevant data within the corridor. This work step will require the involvement of the full suite of representative stakeholders in ICM from State, regional, and local transportation and planning agencies across the full range of roles, including freeway, arterial, and transit program and technical managers, engineers, and analysts; transportation planners; and technical modeling and simulation experts.

3. Model Setup and Calibration

The purpose of this step is to configure the model(s) and tools to reflect the agreed-upon objectives, scope, and parameters of the AMS and to verify proper model calibration to support accurate results. Model setup and calibration represent approximately 35 percent of the total work effort for the AMS initiative. In this step, the baseline model network is developed, including all relevant transportation facilities and modes. In addition, baseline demand modeling is conducted, and the simulation models are calibrated. This step also includes testing sensitivity of the model to understand limitations of the analysis better. This work step can often be the most time-and resource-demanding of the AMS process.

Value. Done correctly, this work step will result in a model with the appropriate robustness and analysis capability to support the analysis in subsequent work steps, and will support risk management for this critical step.

Approach. FIGURE E.5 presents an overview of the substeps related to model setup and calibration work step for the ICM AMS effort. The USDOT has several resources that can provide more specific guidance regarding model calibration in general, including Volume III of the FHWA Traffic Analysis Toolbox.

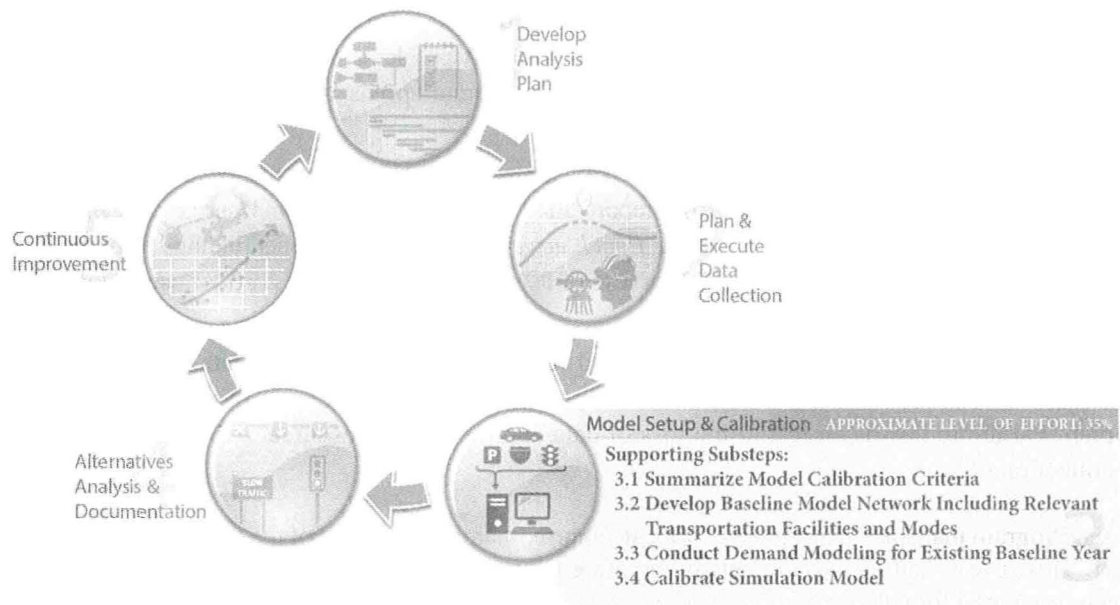


FIGURE E.5. Overview of Workstep 3: Model Setup and Calibration (Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc.).

Calibration criteria should be identified and the selected thresholds documented to establish the benchmarks to be achieved through the process. Documentation provided as part of the FHWA Traffic Analysis Toolbox initiative is useful in establishing these criteria. TABLE E.2 illustrates examples of some of the guideline model calibration criteria established for recurrent congestion used for the ICM Pioneer Sites.

TABLE E.2. Example guideline calibration criteria for recurrent congestion.

Calibration Criteria and Measures	Calibration Acceptance Targets
<ul style="list-style-type: none"> Traffic flows within 15% of observed volumes for links with peak-period volumes greater than 2,000 vph 	<ul style="list-style-type: none"> For 85% of cases for links with peak-period volumes greater than 2,000 vph
<ul style="list-style-type: none"> Sum of all link flows 	<ul style="list-style-type: none"> Within 5% of sum of all link counts
<ul style="list-style-type: none"> Travel times within 15% 	<ul style="list-style-type: none"> >85% of cases
<ul style="list-style-type: none"> Visual Audits— Individual Link Speeds: Visually Acceptable Speed-Flow Relationship 	<ul style="list-style-type: none"> To analyst's satisfaction¹
<ul style="list-style-type: none"> Visual Audits— Bottlenecks: Visually Acceptable Queuing 	<ul style="list-style-type: none"> To analyst's satisfaction

Source: Integrated Corridor Management: U.S. 75 Dallas, Texas—Analysis Plan, FHWA-JPO-10-035, page 37.

Note: The ICM AMS work was conducted while the Traffic Analysis Toolbox Volume III guide was being updated. These calibration criteria were used to augment the 2003 guidance prior to the 2017 guidance becoming formalized. For updated calibration methods for ICM (and other) projects, the reader should reference the 2017 guidance.

¹ The purpose of visual audits (conducted via field visits to observe/inspect congestion hotspots or specific ICM strategies in place along the corridor) is to provide a balanced understanding of congestion patterns and/or opportunities identified through the course of analysis of the archived data.

For incidents, or non-recurring congestion, the following example guideline model calibration criteria were developed as part of the ICM AMS effort (Note: The ICM AMS work was conducted while the Traffic Analysis Toolbox Volume III guide was being updated. These calibration criteria were used to augment the 2003 guidance prior to the 2017 guidance becoming formalized. For updated calibration methods for ICM (and other) projects, the reader should reference the 2017 guidance):

- **Freeway bottleneck locations.** Should be on a modeled segment that is consistent with the location, design, and attributes of the representative roadway section;
- **Duration of incident-related congestion.** Duration where observable within 25 percent.
- **Extent of queue propagation.** Should be within 20 percent.
- **Diversion flows.** Increase in ramp volumes where diversion is expected to take place.
- **Arterial breakdown when incident.** Cycle failures or lack of cycle failures.

TABLE E.3 presents a snapshot of the guideline transit-related calibration criteria used for the U.S. 75 ICM analysis for the Dallas Pioneer Site corridor.

TABLE E.3. Snapshot of guideline transit model validation and calibration criteria for U.S. 75 Integrated Corridor Management—Dallas.

Validation Criteria and Measures	Acceptance Targets
Light-rail station volumes within 20% of observed volumes	For 85% of cases
Light-rail park-and-ride lots	
Parked cars in each lot	Within 30%
Total parked cars for all lots combined	Within 20%

Source: Integrated Corridor Management: U.S. 75 Dallas, Texas—Analysis Plan, FHWA-JPO-10-035, page 37.

Note: The ICM AMS work was conducted while the Traffic Analysis Toolbox Volume III guide was being updated. These calibration criteria were used to augment the 2003 guidance prior to the 2017 guidance becoming formalized. For updated calibration methods for ICM (and other) projects, the reader should reference the 2017 guidance.

Challenges. Some challenges that may be encountered during this work step of the AMS are described below.

- In assessing the model results, the analysts need to weigh the model outputs carefully against the expected outcomes identified in the analysis plan. Where discrepancies exist, further scrutiny is required to assess whether the unexpected outcomes are a result of discrepancies in the model or whether the expected outcomes were not realistic. If the analyst determines that strange model results are a result of model discrepancies, modifications to input parameters may be considered and the alternative rerun; however, it is critical that any modifications to the model inputs be carefully documented and presented in the AMS Report.
- The AMS is designed to provide for an accurate assessment of ICM impacts on performance measures. However, the interpretation of the analysis results often relies on human assessment. Care should be taken to reduce the risks of introducing bias into the interpretation of results by not giving too much weight to analysis capabilities that are not inherent in the AMS. The analysts should make a significant effort to understand the capabilities and limitations of the models and the datasets fully in order to interpret the results objectively.

- The time, staffing, and computing resources required to complete this task can be significant. The analyst managers are encouraged to plan carefully for these resources prior to initiating this task and to provide sufficient flexibility in scheduling these resources to address unforeseen issues that may arise during the work step completion.

Resources. Managers are encouraged to reserve approximately 35 percent of their total project budget for Workstep 3: Model Calibration. The quality of the two preceding steps will facilitate greater ease with this work step; however, calibration involves a certain amount of trial and error, which must be accommodated in the AMS budget and planning. The technical modelers will play primary roles in this work step. Managers must have an understanding of the overall calibration methodology and criteria.

4. Alternatives Analysis and Documentation

The purpose of this step is to identify the optimum combination of ICM strategies for various operational conditions (e.g., varying roadway congestion and transit demand levels; incident conditions; weather conditions affecting operations; presence of work zones; special events) to support effective ICM. This step includes developing future baseline model networks and trip tables for all operational conditions and conducting the alternatives analysis for all ICM strategies. This step assumes that preliminary strategies/alternatives screening has already been performed using sketch planning or other iterative examinations. If all previous steps have been carefully executed, this step represents approximately 30 percent of the total work effort.

Value. The outcomes of this project will include an understanding of predicted effects (including unintended consequences) for various hypotheses of interest, prioritization of ICM alternatives, and a quantified understanding of project benefits and costs. The results will inform ICM deployment decisions and can help build support among broader stakeholders for the ICM system.

Approach. FIGURE E.6 presents an overview of the substeps related to the alternatives analysis.

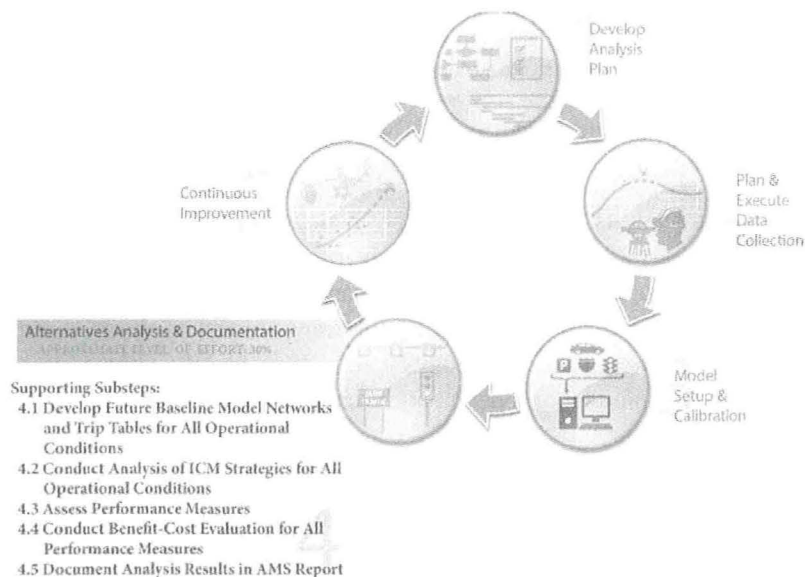


FIGURE E.6. Overview of Workstep 4: Alternatives Analysis and Documentation (Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc.).

Challenges. Some challenges that may be encountered during this work step of the AMS are described below.

- In assessing the model results, the analysts need to weigh the model outputs carefully against the expected outcomes identified in the analysis plan. Where discrepancies exist, further scrutiny is required to assess whether the unexpected outcomes are a result of discrepancies in the model or whether the expected outcomes were not realistic. If the analyst determines that strange model results are a result of model discrepancies, modifications to input parameters may be considered and the alternative rerun; however, it is critical that any modifications to the model inputs be carefully documented and presented in the AMS Report.
- The AMS is designed to provide for an accurate assessment of ICM impacts on performance measures. However, the interpretation of the analysis results often relies on human assessment. Care should be taken to reduce the risks of introducing bias into the interpretation of results by not giving too much weight to analysis capabilities that are not inherent in the AMS. The analysts should make a significant effort to understand the capabilities and limitations of the models and the datasets fully in order to objectively interpret the results.
- The time, staffing, and computing resources required to complete this task can be significant. The analyst managers are encouraged to plan carefully for these resources prior to initiating this task and to provide sufficient flexibility in scheduling these resources to address unforeseen issues that may arise during the work step completion.

Resources. Workstep 4: Alternatives Analysis and Documentation may represent up to 30 percent of the total work effort for AMS, presuming the preceding steps have been comprehensively implemented. This work step requires intensive involvement of both technical modelers and technical project managers of the ICM and/or ICM AMS initiative who have deep understanding of the operational objectives of the proposed ICM strategies. These individuals work collaboratively to assess the various operational alternatives. A critical dependency for this task is a robust Analysis Plan.

5. Continuous Improvement

In this step, practitioners reassess models, model calibrations, and results against observed conditions to validate the AMS approach. Lessons learned are used to improve the process for future deployments, and ongoing performance measurement is used to refine the efficiency of the ICM. This step is ongoing, and consists of the repetition of this process in a manner that reflects and incorporates the data gathering and lessons learned from previous steps. This step represents approximately five percent of the total work effort.

Value. The completion of the continuous improvement work step ensures the maintenance of the models and datasets, greatly reducing the costs, enhancing the ease with which future analyses may be performed on the corridor, and improving the effectiveness in which future investment decisions are made.

Approach. FIGURE E.7 presents an overview of the subtasks and work steps related to incorporating continuous improvement into the AMS process, as documented in the analysis plan. The figure also provides a summary of where this process relates to other recommended work steps in the AMS.

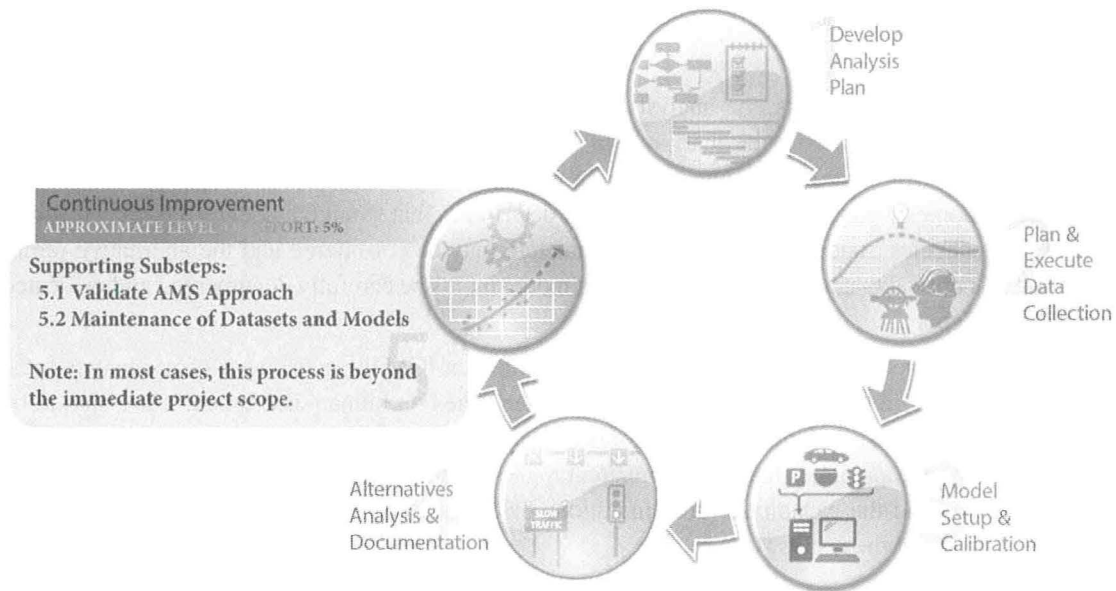


FIGURE E.7. Overview of Workstep 5: Continuous Improvement (Office of the Assistant Secretary for Research and Technology and Cambridge Systematics, Inc.).

Challenges. Some challenges that may be encountered during this work step are summarized below.

- There is a tendency to want to forego this feedback task once the major analysis tasks have been completed. However, this task is critical to improving AMS. Therefore, the resources necessary to complete this ongoing task should be planned for in the analysis plan, and AMS managers should devote adequate effort to ensure its full and successful completion.
- Conducting this work step may require a mindset change for some agencies unaccustomed to these activities. Continuous improvement may require changes to agency policies, work habits, and data processes and systems.

Resources. This final step is ongoing, and represents approximately five percent of the typical project budget (in most cases this process is beyond the immediate project scope). Implementation of the preceding steps in a systematic fashion positions stakeholders to derive long-term value from ICM AMS. The AMS tools are able to be readily updated and adapted to support other decision support needs to continually improve corridor performance.

AMS is not intended to be performed as a one-time, self-contained planning process. Instead, as shown in FIGURE E.8, AMS is intended to be an ongoing, continuously improving process designed to assist practitioners in envisioning, designing, and refining ICM strategies.

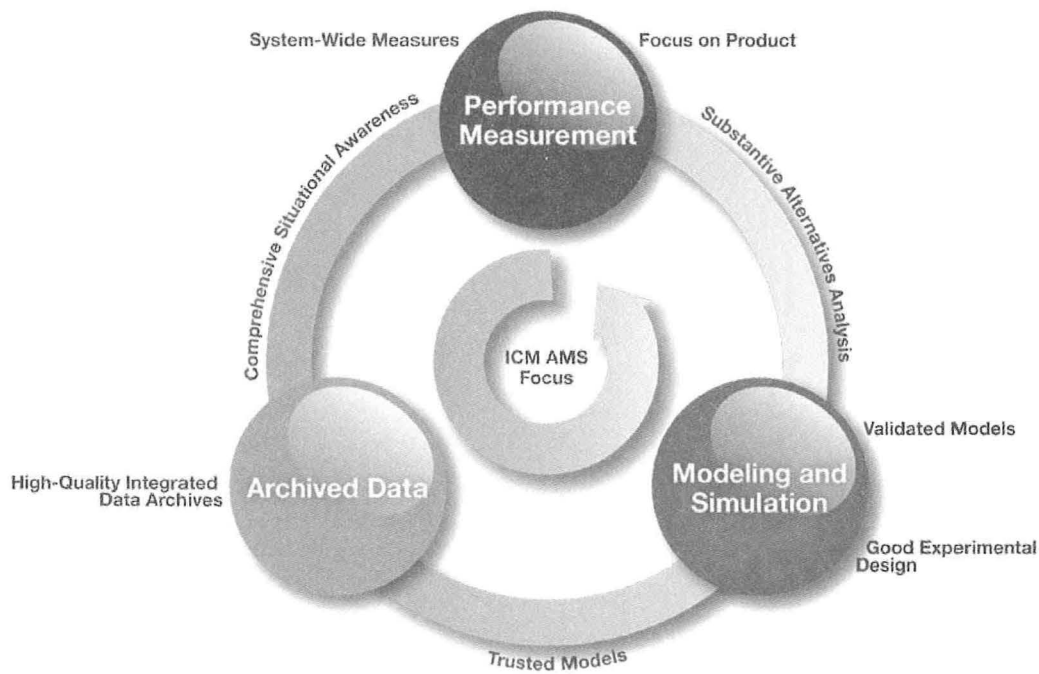


FIGURE E.8. Continuous process improvement for Integrated Corridor Management (Karl Wunderlich, Noblis, 2010).

In this continual cycle of trial and improvement, analytical capital is accumulated. This incrementally increasing knowledge base tends to be self-fulfilling because as improvements are discovered and implemented among the performance measures, modeling and simulation, and archived data processes and systems, further enhancements are encouraged by the resulting improvements in analysis capabilities and greater trust in the model processes and results.

Data Needs Assessment

Once ICM strategies have been narrowed down and key performance measures have been identified, an analysis plan will need to be developed (see Appendix E Workstep 1 for more details). A major component of the analysis plan is data collection, which can include input data for Analysis, Modeling, and Simulation (AMS), performance data for model calibration and validation, and data for ICM approaches and strategies.

This summary of the *AMS Data Collection Plan for the I-15 Pioneer Corridor* outlines the various tasks associated with identifying the data that needs to be collected for application of the ICM AMS tools and strategies to this corridor in order to support benefit-cost assessment for the successful implementation of ICM.

Principles in Developing and Executing the Data Collection Plan

A number of principles apply in developing and executing the data collection plan. These are summarized as follows:

- **Resource and Timeframe Constraint**—The overall ICM AMS effort must take place within the budget and timeframe specified in the analysis plan. In particular, available data at the San Diego Pioneer Site will be leveraged in the AMS effort.
- **Recognize Current Limitations in Available Data**—There are known gaps in the available data that must be bridged by collecting additional field data and deriving estimates for other missing data.
- **Collate Information on Current and Future Traffic Management Systems**—The data collection plan also includes a listing of the resources used by the AMS team to obtain information about current and future (planned) systems that will be replicated in the AMS effort. These systems include hardware components, operational characteristics, and creation and modification attributes, which will be summarized to the extent possible by the AMS team. Any significant assumptions that would be required because of absence of any such information will be provided in the Analysis plan.
- **Correlation between Data Collection for Model Calibration and 2003 Baseline Year**—2003 is the base year selected for analysis since it is the most appropriate time period when there was no significant construction activity happening along the I-15 corridor and for which there is a validated travel demand model. A significant portion of the data collected is for purposes of model calibration and validation for this baseline year.

Corridor Site and Description

The Pioneer Site identified for this analysis is the Interstate 15 (I-15) corridor in San Diego, California. The corridor extends from the interchange with State Route (SR) 163 in the south to the interchange with SR 78 in the north, a freeway stretch of approximately 20 miles. Also included in the study area are the roadways discussed below.

This appendix outlines the AMS Data Collection plan for the I-15 ICM Corridor in San Diego County. The focus of this appendix is on the specific types of data that currently are available, whether in electronic or paper form, including listings of signalized arterial intersections with signal timing plans, volume of through traffic, turning movements, and speeds. In addition, it identifies the gaps in the data where additional data collection is required for the analysis, modeling, and simulation tasks.

The I-15 Corridor Site extends from the interchange with SR 163 in the south to the interchange with SR 78 in the north, a freeway stretch of 21 miles. Also included in the study area are the following seven primary arterial roadways:

- Centre City Parkway.
- Pomerado Road.
- Rancho Bernardo Road.
- Camino Del Norte Road.
- Ted Williams Parkway.
- Black Mountain Road.
- Scripps Parkway/Mercy Road.

FIGURE F.1 illustrates the study area and its roadways that will be utilized for analysis of this Pioneer Site. I-15 is divided into three sections (pink, orange, and green) corresponding to the three separate roadway sections under construction as part of the new Managed Lanes with Congestion Pricing facility.

I-15 is an eight to 10-lane freeway section in San Diego providing an important connection between San Diego and cities such as Poway and Escondido, and destinations to the northeast. The current operations on I-15 include two center-median lanes that run along eight miles of I-15 between SR 163 in the south and Ted William Parkway (SR 56) in the north. These center-median lanes are reversible high-occupancy vehicle (HOV) lanes that are being operated in a 2+2 configuration except on Thursday mornings where it uses a 3 southbound + 1 northbound configuration. The current operations also allow single-occupancy vehicles (SOV) to utilize the roadway for a price, effectively operating as high-occupancy toll (HOT) lanes. The section between SR 78 and SR 163 (study area) will eventually include four center median lanes, which will have three lanes operating as HOT lanes in the peak direction.

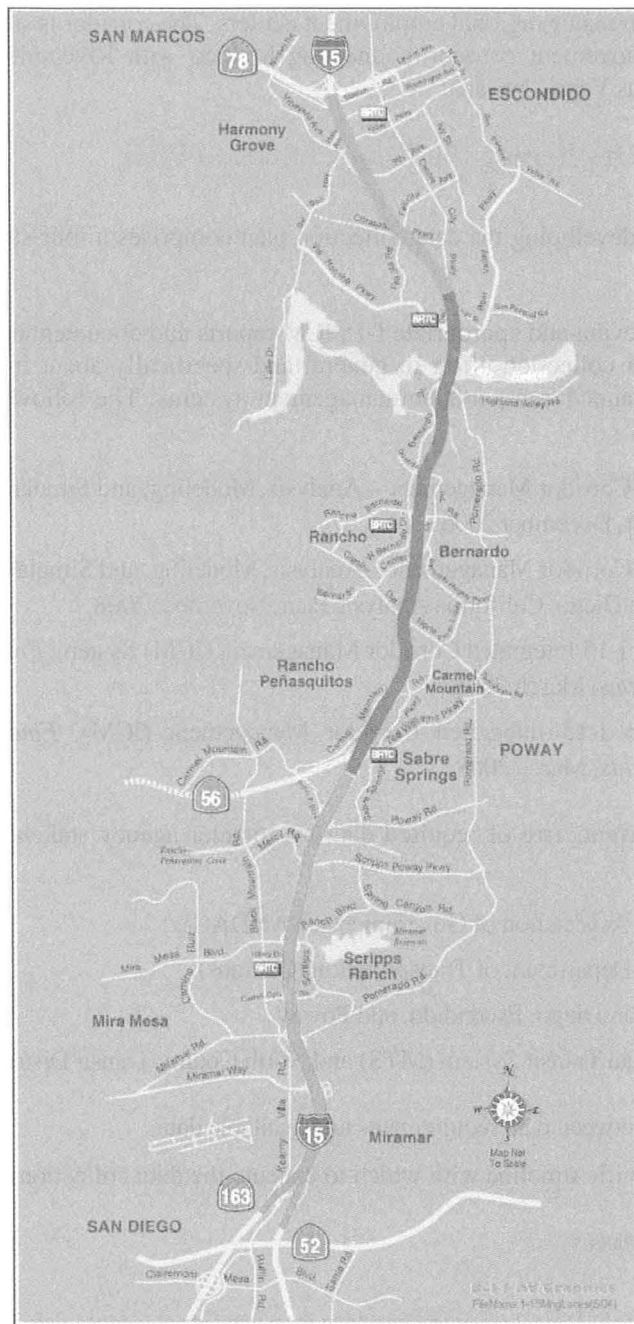


FIGURE F.1. San Diego I-15 Integrated Corridor Management study area (San Diego Association of Governments AV Graphics, 2008).

According to the Concept of Operations (CONOPS) report for this corridor, current weekday traffic volumes range from 170,000 to 290,000 vehicles on the general-purpose lanes of I-15, and approximately 20,000 vehicles use the I-15 Express Lanes during weekdays. The I-15 corridor, one of three primary north-south transportation corridors in San Diego County, is the primary north-south highway in inland San Diego County, serving local, regional, and interregional travel. The corridor is a heavily utilized regional commuter route, connecting communities in northern

San Diego County with major regional employment centers. The corridor is situated within a major interregional goods movement corridor, connecting Mexico with Riverside and San Bernardino Counties, as well as Las Vegas, Nevada.

Methodology for Developing the Data Collection Plan

The methodology for developing the data collection plan comprises a four-step process described as follows:

1. Review all relevant and appropriate I-15 ICM reports and documentation that deal with the I-15 ICM data collection effort in general and specifically about information regarding current and planned transportation management systems. The following resource list has been reviewed:
 - Integrated Corridor Management—Analysis, Modeling, and Simulation *Sample Data List* draft report, December 2006.
 - Integrated Corridor Management—Analysis, Modeling, and Simulation for the San Diego I-15 in San Diego, California Analysis Plan, November 2008.
 - San Diego I-15 Integrated Corridor Management (ICM) System, *Final I-15 ICM Concept of Operations*, March 2008.
 - San Diego I-15 Integrated Corridor Management (ICM), *Final I-15 ICM System Requirements*, March 2008.
2. Assess the current state of required data by corridor agency stakeholders, including the following:
 - San Diego Association of Governments (SANDAG).
 - California Department of Transportation (Caltrans).
 - Cities of San Diego, Escondido, and Poway.
 - Metropolitan Transit System (MTS) and North County Transit District (NCTD).
3. Identify gaps between data requirements and available data.
4. Develop a specific timeline with which to execute the data collection.

Documentation Review

The purpose of the *Sample Data List* memorandum is to provide a sample data list for the AMS work to be conducted, which includes the following:

- Input data for AMS.
- Performance data for model calibration and validation.
- Data for ICM approaches and strategies.

Input data for AMS is organized into the following components:

- Network.
- Travel Demand.
- Traffic Control.
- Transit.
- ITS elements.

TABLE F.1 below provides a summary of the input data required for AMS. The *Sample Data List* memorandum provides a full description of each of these input data components.

TABLE F.1. Input data for analysis, modeling, and simulation.

Network	Travel Demand	Traffic Control	Transit	ITS Elements
Link Distances	Link Volume	Freeways	Transit Routes	Surveillance System
Free-flow Speeds	Traffic Composition	Ramp Metering	Transit Stops	<i>Detector Type</i>
Geometrics—Freeways	On- and Off-Ramp Volumes	<i>Type (local, system-wide)</i>	Location	<i>Detector Spacing</i>
<i># Travel Lanes</i>	Turning Movement Counts	<i>Detectors</i>	Geometrics	<i>CCTV</i>
<i>Presence of Shoulders</i>	Vehicle Trip Tables	<i>Metering Rates</i>	Dwell Times	Information Dissemination
<i># HOV Lanes (if any)</i>	Person Trip Tables	<i>Algorithms (adaptive metering)</i>	Transit Schedules	<i>CMS</i>
<i>Operation of HOV Lanes</i>	Transit Ridership	Mainline Control	Schedule Adherence Data	<i>HAR</i>
<i>Accel/Dec Lanes</i>		<i>Metering</i>	Transfer Locations	<i>Other (e.g., 511)</i>
<i>Grade</i>		<i>Lane Use Signals</i>	Transit Speeds	<i>In-vehicle Systems</i>
<i>Curvature</i>		<i>Variable Speed Limits</i>	Transit Fares	Incident Management
<i>Ramps</i>		Arterials	<i>Payment Mechanisms</i>	<i>Incident Detection</i>
Geometrics—Arterials		Signal System Description	Paratransit	<i>CAD System</i>
<i>Number of Lanes</i>		<i>Controller Type</i>	<i>Demand-responsive</i>	<i>Response and Clearance</i>
<i>Lane Usage</i>		<i>Phasing</i>	<i>Rideshare programs</i>	<i>Incident Data Logs</i>
<i>Length of Turn Pockets</i>		<i>Detector Type and Placement</i>		Tolling System
<i>Grade</i>		<i>Signal Settings</i>		<i>Type</i>

Network	Travel Demand	Traffic Control	Transit	ITS Elements
<i>Turning Restrictions</i>		Signal Timing Plans		<i>Pricing Mechanisms</i>
<i>Parking</i>		Transit Signal Priority System		TMC
Parking Facilities		<i>Control Logic</i>		<i>Control Software/Functions</i>
<i>Location</i>		<i>Detection</i>		<i>Communications</i>
<i>Capacity</i>		<i>Settings</i>		<i>Data Archival Dissemination</i>
Park and Ride Lots		Emergency Preemption System		Transit/Fleet Management System
<i>Location</i>		<i>Control Logic</i>		AVL
<i>Capacity</i>		<i>Detection</i>		<i>Communications</i>
		<i>Settings</i>		<i>Traveler Information Bus Stops</i>
	These data must be provided for all links in the corridor study area.			
	These data must be provided for a consistent analysis period, including the same date for data from all facilities in the corridor area.			
	To facilitate the assessment of variability in traffic volumes and speeds, data must be provided for multiple days of the week and months of the year for all facilities in the study corridor.			

Source: *Sample Data List*, December 2006.

Performance data for model calibration and validation is based on a three-step framework for microscopic models that is described in the Sample Data List. The framework suggests that the following data are important for model calibration and performance analysis:

- Capacity at bottleneck locations.
- Traffic volumes at key network locations.
- Travel times on network links.
- Spatial and temporal extent of queuing.

TABLE F.2 shows the data requirements for the San Diego I-15 ICM approaches and strategies based on work performed in the development of the analysis plan, which in turn, was formulated from the CONOPS. The table is configured as a matrix with ICM approaches and strategies, together with the AMS input data components.

TABLE F.2. Data requirements for San Diego I-15 Integrated Corridor Management approaches and strategies.

ICM Approaches and Strategies	Data Requirements				
	Network Data	Demand	Control	Transit	ITS Elements
ATIS pre-trip information	X	X			X
ATIS en-route traveler information	X	X			X
Signal priority to transit	X	X	X	X	X
Coordinated operation ramp meters and arterial traffic signals	X		X		X
Physical Bus Priority			X	X	
Modify ramp metering rates to accommodate traffic shifting from arterial		X	X		
Modify HOV restrictions	X	X		X	
Congestion pricing on Managed Lanes		X			

Source: *Sample Data List*, December 2006.

TABLE F.3 maps the data shown per category in TABLE F.2 with the ICM Approaches and Strategies to produce the sample data list for each ICM strategy.

The *Concept of Operations and System Requirements* documents provide information on the I-15 ICM System currently including existing and planned-for systems together with a timeline for their implementation. Of particular relevance to and importance for the data collection plan are the Intermodal Transportation Management System (IMTMS) and the Decision Support System (DSS). The IMTMS system is an existing data acquisition and dissemination network within the San Diego region; it is, in turn, connected to a number of existing and planned external systems in the region including, but not limited to, the Regional Arterial Management System (RAMS), the Regional Transit Management System (RTMS), and the Advanced Traffic Management System (ATMS) 2005.

Since these systems will be replicated in the course of the AMS effort, the team is collecting data/information about such systems as they relate to the selected ICM strategies and application scenarios.

TABLE F.3. Data list for San Diego I-15 Integrated Corridor Management approaches and strategies.

ICM Approaches and Strategies	Data Requirements				
	Network Data	Demand	Control	Transit	ITS Elements
ATIS pre-trip information	Link distances, geometrics	Link volumes			
ATIS en-route traveler information	Link distances, geometrics	Link volumes			
Signal priority to transit	Link distances, free-flow speeds, geometrics (arterials)	Link volumes, turning movement counts, transit ridership	Arterial signal timing plans, transit signal priority system, QuicNet 4+ system	Transit routes, stops, schedules, schedule adherence data, speeds	
Coordinated operation ramp meters and arterial traffic signals	Link distances, free-flow speeds, geometrics		Freeway ramp metering, arterial signal timing plans, QuicNet 4+ system		
Physical Bus Priority					
Modify ramp metering rates to accommodate traffic shifting from arterial	Link volumes, on-ramp volumes, turning movement counts		Freeway ramp metering		
Modify HOV restrictions	Geometrics (freeway)			Paratransit, transit routes	
Congestion pricing on Managed Lanes					

Source: *Sample Data List*, December 2006.

Current State of Required Data and Gap Identification

The current state of required data varies by individual network: arterial, freeway, and transit. Each is presented in separate sections of this appendix.

Arterial-Related Data

TABLE F.4 below provides an example of the data available along the seven arterials included in the study area. Data requested or obtained for these arterials includes the following:

- Signal timings.
- Vehicle through volumes.
- Turning movement counts.
- Pedestrian volumes.

Where data is present, cells are either marked with a “Y” (for yes, data available) or with the year data is available. Empty cells indicate locations where data currently is unavailable. In addition, cells marked with “NA” under the signal timing plans column indicate that these intersections are unsignalized. Any missing signal timing plans have been requested from both Caltrans and local government agencies. Acquiring vehicle turning movement counts, on the other hand, will be subcontracted to a data collection firm for all 107 intersections, as there appears to be a significant gap in the availability of traffic count information along the arterials. Turning movement counts will be conducted on typical weekdays (Tuesday, Wednesday, and Thursday) during the a.m. peak period between the hours of 5:00 a.m. and 10:00 a.m. Counts will be conducted preferably within a similar timeframe window (a minimum of two weeks).

TABLE F.4. Example of data availability and gaps on arterials.

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
1	Black Mountain Road at Activity Road	Y	2001	2001	2001	Y
2	Black Mountain Road at Canyonside Park	Y				Y
3	Black Mountain Road at Capricorn Way	Y	2003	2003	2003	Y
4	Black Mountain Road at Carmel Mountain Road	Y	2002	2002	2002	Y
5	Black Mountain Road at Carmel Valley Road					Y
6	Black Mountain Road at Carroll Canyon Road	Y				Y
7	Black Mountain Road at Carroll Center Road	Y	2002	2002	2002	Y
8	Black Mountain Road at Emden Road	N/A	2002	2002	2002	Y
9	Black Mountain Road at Galvin Avenue	Y	2003	2003	2003	Y
10	Black Mountain Road at Gemini Avenue	Y	2003	2003	2003	Y

Source: *Sample Data List*, December 2006.

Freeway-Related Data

Caltrans' Performance Measurement System (PeMS) web site is capable of providing freeway data as fine as 30-second intervals. PeMS data is collected and archived 24/7 for all operating loop detectors on the freeway system, and the data obtained from it can be aggregated to any time interval: <http://pems.eecs.berkeley.edu/>. An example of the availability of PeMS data is shown in TABLE F.5.

In addition to PeMS data, the following freeway-related information also is available from Caltrans and other public agencies:

- California Highway Patrol (CHP) computer-aided dispatch (CAD) logs are available for freeway incidents, which provides data including date, time, location, lane number, incident type, incident impact (e.g., lane closure, traffic backup).
- Caltrans' Advanced Transportation Management System (ATMS 2005) contains the following data.
 - Freeway congestion.
 - Freeway incidents.
 - Travel times.
 - Planned events.
 - Changeable message sign (CMS) status and current messages.
 - Closed-circuit television (CCTV) imagery.
 - Coverage of vehicle detection system (VDS) along I-15 (location and loop status).
 - Snapshots of freeway loops.
- Freeway ramp metering rates include the following:
 - Cycles/minute.
 - Vehicles/cycle.
 - Vehicles/hour/lane.
 - Seconds/cycle.
 - Vehicles per hour.
 - Occupancy.

A request has been made to obtain this data for a set of 62 I-15 ramps (both northbound and southbound).

- Caltrans signal phasing/timing plans at on- and off-ramps to I-15 freeway.
- ITS operations along I-15 freeway, including traffic control systems (signal systems, emergency preemption, and ramp metering) and ITS elements (surveillance systems, information dissemination, incident management, and traffic management center or TMC).
- Speed limit information for Baseline Year (2003) on I-15 and primary arterials: AMS Team has received a Geographic Information System (GIS) layer from Caltrans District 11 regarding this data.

TABLE F.5. Example of I-15 northbound PeMS data.

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
1	I-15 ML	I-15 NB to HOV	FWY TO FWY		Y
2	I-15 ML at SR 163	I-15 NB HOV On from SR 163	FWY TO FWY		Y
3	SR 163	I-15 NB at SR 163	FWY TO FWY		Y
4	Miramar Way Collector Distributor	Mainline	MANUAL	Y	Y
		15 NB Off to Miramar CD	TMC		Y
		Loop on from Miramar Way CD			
		Loop Off to Miramar Way CD			
		I-15 NB On from Miramar CD		Y	Y
5	Miramar/Pomerado Road	Mainline	MANUAL		
		Miramar/Pomerado Rd at I-15 NB Diag Off and On Ramps	TMC	Y	Y
		I-15 NB Loop On from Pomerado Road		Y	Y
6	Carroll Canyon Road	Mainline	MANUAL	Y	Y
		I-15 NB on and off ramp at Carroll Canyon Road	TMC	Y (only for On)	Y
7	Mira Mesa Boulevard	Mainline	MANUAL	Y	Y
		I-15 NB Diag On from Mira Mesa Boulevard	TMC	Y	Y
		I-15 NB Diag Off to and Loop On from Mira Mesa Boulevard		Y	Y
8	Scripps Poway Parkway/Mercy Road	Mainline	MANUAL	Y	Y
		I-15 NB On and Off ramps at Scripps Poway	TMC	Y (only for On)	Y (only for On)
9	Rancho Penasquitos/Poway Road	Mainline	MANUAL	Y	Y
		I-15 NB Diag Off at Rancho Penasquitos	TMC		Y
		I-15 NB Loop On from Rancho Penasquitos Boulevard		Y	Y
		I-15 NB Diag On from Ranchos Penasquitos			

Source: *Sample Data List*, December 2006.

Transit-Related Data

In addition to data along freeways and arterials, the availability of transit-related information along the Corridor also has been assessed. The I-15 Corridor is primarily serviced by the following six bus routes:

- Premium Express Bus Route 810—Escondido to Downtown San Diego.
- Premium Express Bus Route 820—Poway to Downtown.
- Premium Express Bus Route 850—Rancho Peñasquitos to Downtown.
- Premium Express Bus Route 860—Rancho Bernardo to Downtown.
- Express Service Bus Route 20—Downtown San Diego to North County Fair.
- Express Service Bus Route 210—Mira Mesa to Downtown San Diego.

Bus schedules and route information are available through the local transit agency, San Diego MTS. We currently are collecting the following transit-related data from MTS and SANDAG; data collection is scheduled for completion in December 2008:

- For the 800 series and Routes 20 and 210 MTS bus routes, we have the following:
 - Passenger survey data between 1995 and 2008.
- For the two express service Routes 20 and 210, we have the following:
 - Automatic vehicle location (AVL) data (schedule adherence) as far back as 2007; and
 - Automatic passenger counter (APC) data as far back as 2006.
- We have multiple databases of incident data (accident logs, incident logs, interrupted service occurrence logs) going back as far as 2001. Data will be supplied on a DVD.

Timeline Schedule for Data Collection

Travel Time Runs (Arterial and Freeway Locations)

Following the boundaries of the study area, as shown in FIGURE F.1, TABLE F.6 lists the locations of the travel time runs that have been requested from the subcontracted data collection firm, *National Data & Surveying Services (NDS)*. Travel time runs are being conducted along the freeway and arterials during the a.m. peak period between the hours of 5:00 and 9:00 a.m. beginning the week of January 5, 2009. Two runs are being conducted for each segment during a period of two typical weekdays (Tuesday, Wednesday, or Thursday), for a total of four runs per location.

TABLE F.6. Travel time run locations.

Location	From	To
Pomerado Road	I-15	Highland Valley Road
Centre City Parkway	I-15	I-15
Rancho Bernardo Road	Pomerado Road	Camino Del Norte
Camino Del Norte	Pomerado Road	Rancho Bernardo Road
Ted Williams Parkway (SR 56)	Pomerado Road	Black Mountain Road
Black Mountain Road	Pomerado Rd/Miramar Road	SR 56
Scripps Parkway/Mercy Road	Pomerado Road	Black Mountain Road
I-15 Southbound and Northbound	SR 52	SR 78

Source: *Sample Data List*, December 2006.

Arterial Data Collection

Originally, there were 106 arterial intersections listed in TABLE F.4 for which turning movement counts are being collected by NDS between the hours of 5:00 and 10:00 a.m., beginning the week of January 5, 2009. Of the 106 arterial intersections, 91 require one person, while the remaining 15 intersections require two people to collect the data.

Freeway Data Collection

TABLE F.5 depicts an example of the I-15 on- and off-ramp locations of available PeMS data and data gaps. This data is not, however, being collected because the physical configuration has changed from that which existed in 2003. Moreover, time and resource constraints also have contributed to this data not being collected.



APPENDIX G

Documentation for Integrated Corridor Management Deployments

While ICM projects are centered on stakeholder coordination, the ICM system (ICMS) provides the backbone that enables centralized data collection, incident detection, response plan implementation and automatic information dissemination. Each ICMS is designed to address the specific needs of the ICM corridor at hand. Various levels of integration and automation can be built in, depending on the assets and funding available. This appendix presents details of three ICMSs:

1. Dallas U.S.-75 ICMS—System is based on a set of preapproved response plans.
2. San Diego I-15 ICMS—System allows for the dynamic generation of response plans.
3. Kansas City I-35 ICMS—System is under development.

Dallas (U.S.-75) Integrated Corridor Management System

The details presented here on the Dallas U.S.-75 ICMS are based on FHWA's ICM Analysis, Modeling, and Simulation for the U.S-75 Corridor in Dallas, Texas Post-Deployment Report¹⁹, as well as the Development of TEARS Incident Signal Timing Plans technical memorandum developed by Kimley-Horn and Associates Inc., dated March 25, 2014.

For reference, the following strategies were included in the Dallas U.S.-75 ICM deployment:

- Providing improved multimodal traveler information (pretrip, en-route), such as:
 - New 511 system (real-time information, including traffic incident information, construction information, traffic speeds, light rail transit (LRT) passenger loads, LRT vehicle locations, Red Line park-and-ride utilization).
 - My511 e-mail alerts.
 - ICM dynamic message signs (DMS) messages.
 - Social media.
 - Dallas Area Rapid Transit (DART) data feeds for third-party application development.
- Implementing a parking management system at Red Line park-and-ride facilities.
- Developing preapproved ICMS response plans.
- Developing a Decision Support System to support ICM strategy identification and selection.

¹⁹ Federal Highway Administration, *Integrated Corridor Management Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas Post Deployment Assessment Report*. FHWA-JPO-16-396, November 2016. Available at: <https://ntl.bts.gov/lib/60000/60400/60490/FHWA-JPO-16-396.pdf>.

- Diverting traffic to key frontage roads and arterials (Greenville Ave.) with coordinated and responsive traffic signal control.
- Encouraging travelers to use transit during major incidents on the freeway.
- Increasing utilization of Red Line capacity with the potential of additional train cars or decreased headways.

The Dallas U.S.-75 ICMS integrated various regional and municipal systems and operations using a decentralized approach. Through wireless and web-based alerts, as well as dynamic message signs, travelers received increased access to real-time information on traffic conditions, travel times, public transit schedules, and parking availability, which can help them plan their routes and make adjustments as needed in response to changing conditions.

One component of the process was to deploy adjusted traffic signal timing as a means of mitigating congestion when on-freeway incidents cause traffic to divert to the arterial street network. Freeway incidents occur at various locations, directions and times of the day. Incidents have widely differing severity, duration and resulting impact on traffic. In order to determine the incident types most in need of having pre-developed signal timing adjustment strategies, Texas A&M Transportation Institute (TTI) performed a clustering method of historical traffic events along U.S.-75 within the project area. This analysis used parameters such as crash severity (e.g., number of lanes affected and duration), direction, time of day, weather, and U.S.-75 traffic demand. TTI also modeled the probable traffic shifts that would occur because of these frequently occurring incident types using Dynamic Intermodal Routing Environment for Control and Telematics (DIRECT), the ICM mesoscopic model developed by Southern Methodist University (SMU).

Targeted Event Accelerated Response System (TEARS) is the U.S.-75 ICM component that includes the implementation of traffic signal timing changes to mitigate specific incident types. TEARS signal timing plans were developed using the time-of-day dependent clusters (i.e., AM, mid-day, PM periods) resulting from TTI's analysis, which were prioritized based on their delay impact on U.S.-75 and the surrounding roadway network. The plans were tuned with help from AMS in the form of probable traffic volume changes modeled by SMU's DIRECT model.

The expert rules outlined in TABLE G.1 serve as a filtering mechanism to select the appropriate response plan from the set number of preapproved response plans. The values used for implementation were determined based on the consensus of the operational stakeholders. At the time these criteria were developed it was recognized that "Established criteria values can be subject to change based on experience and post-implementation analysis." Many crashes will never meet all of the conditions required to recommend a multiagency action plan. Once a crash meets the criteria for coordinated action across agencies, a recommendation is sent to the ICM Coordinator and the affected agencies, and the ICM Coordinator initiates field implementation, as appropriate.

For example, an incident is classified as a minor incident with short diversion to frontage road if it affects one or more general purpose and/or high-occupancy vehicle (HOV) lanes, *and* has a queue length between 0.5 mile to 0.99 mile; defined as average speed of the consecutive U.S.-75 links upstream of incident (same direction) greater than 30 miles per hour, *and* the average speed of the frontage road links (same direction) between first available on-ramp downstream of incident to one-mile upstream of the incident is greater than 20 miles per hour, *and* prediction measures of performance (MOPs) is <0% for U.S.-75 (same direction) and <2% for the entire network. However, if the U.S.-75 queue length is > one-mile *and* all other conditions are the same then it is classified as a major incident with long diversion to frontage road.

TABLE G.1. Expert rules for response plan recommendation.

Strategies	No. Affected Lanes General Purpose and HOV	Main Lanes		Speed FR (on Diversion Route) (mph)	Speed GV (on Diversion Route) (mph)	Prediction Δ MOP Plan versus Do Nothing	Park and Ride Utilization	Light Rapid Transit Utilization
		Speed (mph)	Queue Length Derived from Avg. Speed (mi.)					
Minor Incident: Short Diversion to FR.	≥ 1	< 30	$0.5 < Q < 1$	> 20	N/A	$< 0\%, < 2\%$	N/A	N/A
Major Incident: Long Diversion to FR.	≥ 1	< 30	$Q \geq 1$	> 20	N/A	$< 0\%, < 2\%$	N/A	N/A
Major Incident: Diversion to FR. GV.	≥ 2	< 30	$Q \geq 1$	< 20	> 20	$< 0\%, < 2\%$	N/A	N/A
Major Incident: Diversion to FR. & GV., Transit	≥ 2	< 30	$Q > 4$	< 20	< 20	$< 0\%, < 2\%$	$< 85\%$	$< 85\%$
Major Incident: Diversion to FR. and GV., Stop Transit Diversion (No DMS action)	≥ 2	< 30	$Q > 4$	< 20	< 20	$< 0\%, < 2\%$	$> 85\%$	$> 85\%$

Source: Texas A&M Transportation Institute.

When an incident occurs along the Dallas U.S.-75 ICM corridor, which fulfills the criteria to recommend a DSS plan (otherwise known as an Implementable DSS Plan), the ICM Coordinator evaluates the response plan and approves it for the operating agencies to recommend. The plan consists of one or more of the following actions: dynamic message sign message (e.g., “Try Greenville Ave.”), traffic signal timing adjustment, added rail capacity, or parking utilization. Simultaneously, information regarding the incident is made available via 511, agency Web sites, social media, etc., which is also available for incidents that did not generate an Implementable DSS plan (also known as Information Only Plans).

FIGURE G.1 and FIGURE G.2 provide examples of an Implementable DSS Plan and the actions required of each agency involved. Each Flex Group number corresponds to a specific signal timing scheme for a specified set of traffic signals. Each impacted city (e.g., Richardson, Plano, etc.) is responsible for activating the correct Flex Group plan and monitoring traffic every 15 minutes to determine if the response plan is clearing the congestion caused by the incident.

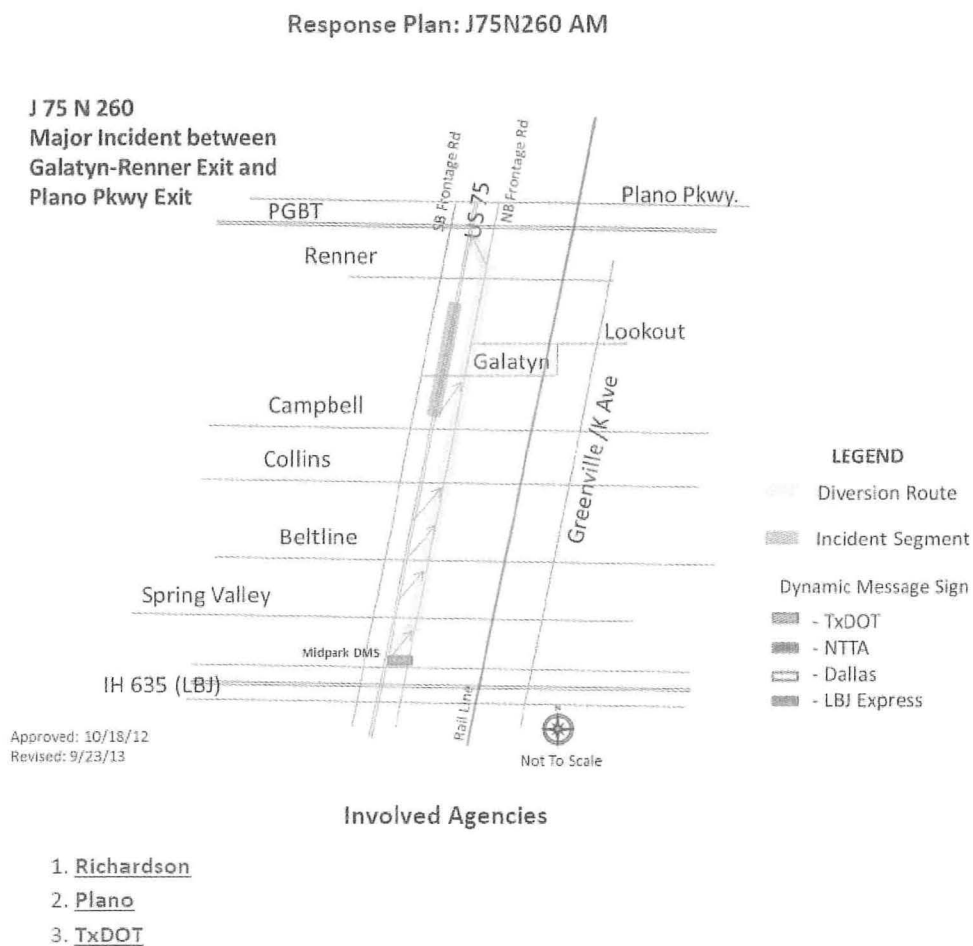


FIGURE G.1. Response plan J75N260 AM—diversion plan (Implementable Response Plans for Stage 3, Texas A&M Transportation Institute, November 18, 2013, page 84, unpublished).

Required Actions

Richardson

- Activate Flex Group 19 and monitor every 15 min. Applicable only during AM Peak Period (6-9am).

Plano

- Activate Flex Group 19 and monitor every 15 min. Applicable only during AM Peak Period (6-9am).

No.	Signal	TEARS/ DIRECT ID	CITY	Flex Group	SmartNet ID
1	Arapaho @ US 75 NBFR	4227	RIC	19	1010154650
2	Arapaho @ US 75 SBFR	182	RIC	19	1010154640
3	Campbell @ US 75 NBFR	4355	RIC	19	1010139300
4	Campbell @ US 75 SBFR	4352	RIC	19	1010139290
5	Renner @ US 75 NBFR	4303	RIC	19	1010154860
6	Renner @ US 75 SBFR	4306	RIC	19	1010154850
7	Plano Rd @ Renner	4300	RIC	19	1010154870
8	Park Blvd @ Republic	17	PLA	19	1010147320

TxDOT

- DMS:

Message ID	Name	SmartNet ID
1	HOV 75_NB Midpark	5074890

FIGURE G.2. Response plan J75N260 AM—required actions. (Implementable Response Plans for Stage 3, Texas A&M Transportation Institute, November 18, 2013, page 85, unpublished).

San Diego (I-15) Integrated Corridor Management System

The details presented here on the San Diego I-15 ICMS are based on FHWA's ICM Analysis, Modeling, and Simulation for the I-15 Corridor in San Diego Post-Deployment Report²⁰.

For reference, the following strategies were included in the Dallas U.S.-75 ICM deployment:

- Active Decision Support System (DSS).
- Coordinated incident management.
- Freeway coordinated ramp metering.
- Actionable traveler information (en-route and pre-trip via CMS, a new 511 app, and other commercial sources).

²⁰ Federal Highway Administration, *Integrated Corridor Management Analysis, Modeling, and Simulation for the I-15 Corridor in San Diego, California Post Deployment Assessment Report*. FHWA-JPO-16-403, December 2016. Available at: <https://ntl.bts.gov/lib/61000/61100/61131/FHWA-JPO-16-403.pdf>.

- Upgrades to selected traffic signal systems (new traffic signal coordination timings, responsive traffic signal control).
- Alternate route wayfinding signs.

The San Diego I-15 ICMS integrated existing systems with new or updated systems. The ICMS system design can be seen in FIGURE G.3. The ICMS consists of the following key components: 1) Data Hub—collection of external systems operated by corridor stakeholder agencies providing data to the ICMS and/or receiving control requests from the system via a standardized regional communication network called the Intermodal Transportation Management System (IMTMS); 2) Decision Support System (DSS)—tool to help system operators identify incidents and implement response plans aimed at minimizing the impacts of identified incidents on corridor operations; and 3) System Services—services to assist with data management, system management, system maintenance, and training activities (e.g., ICMS data stores, corridor performance management).

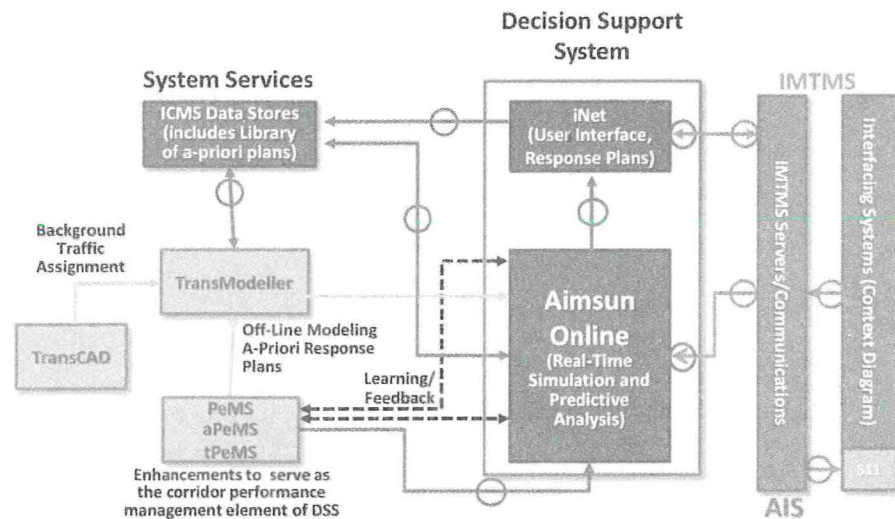


FIGURE G.3. San Diego I-15 Integrated Corridor Management system design (ITS 3C Summit San Diego I-15 Integrated Corridor Management System presentation, September 16, 2014, unpublished).

As shown in FIGURE G.4, the ICMS interfaces with a variety of systems (color coded based on facility type/functionality) that are managed by different agencies, including freeway systems in turquoise—Lane Closure System, Ramp Meter Information System, Advanced Traffic Management System, Congestion Pricing System, Corridor Performance Monitoring System; arterial systems in yellow—Regional Arterial Management System; transit systems in lavender—Regional Transit Management System, Smart Parking System; public safety in purple—Regional Event Management System; and advanced traveler information systems (ATIS) in orange—Arterial Travel Time System, Traveler Information Systems, Weather Information System.

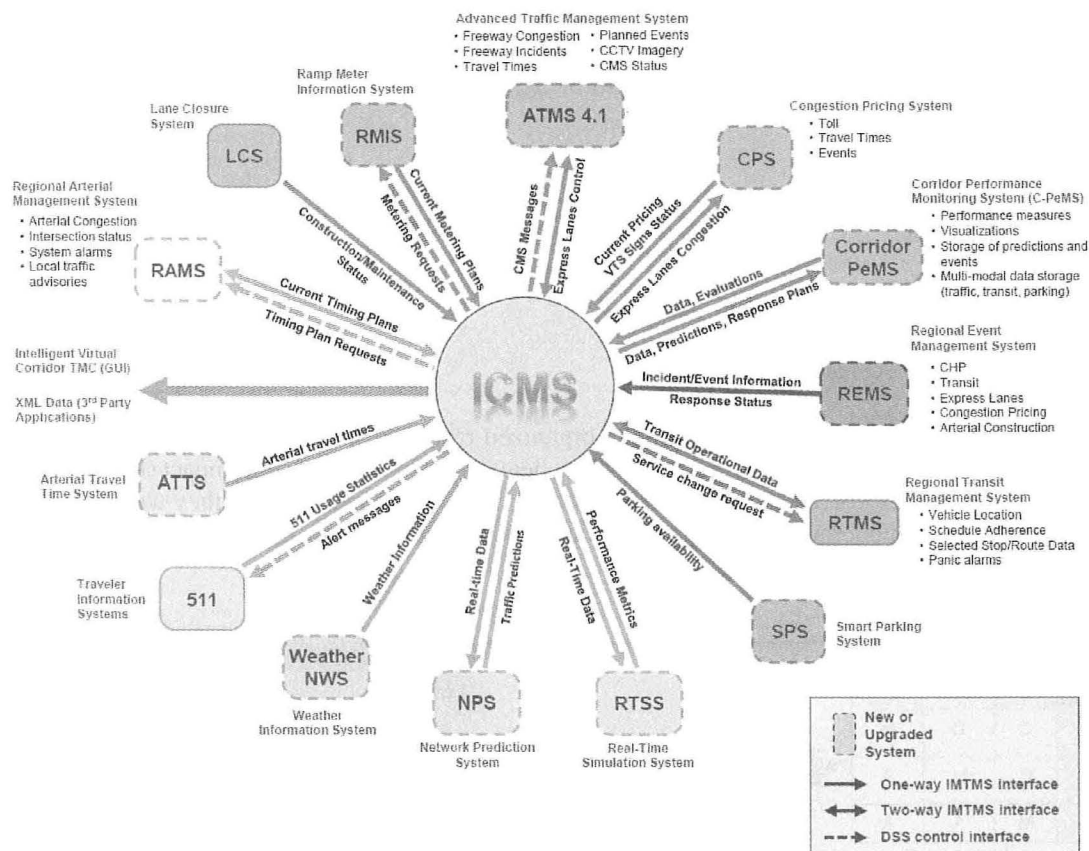


FIGURE G.4. San Diego I-15 Integrated Corridor Management system inputs and outputs (San Diego I-15 Demonstration Integrated Corridor Management System PATH Report on Stage 3: Site Demonstration and Evaluation, UCB-ITS-PRR-2015-03, page 32.)

The innovative element of the DSS lies in its ability to forecast and simulate corridor performance issues using near real-time simulation and continuous predictive analysis, promoting proactive courses of action for recurrent and non-recurrent conditions (e.g., bottlenecks, incidents) which are coordinated among *all* corridor stakeholders. While the existing IMTMS network already facilitated decision-making by enabling interagency information sharing, it did not offer the functionality needed to integrate this information into actionable traffic control strategies. The DSS filled this gap by providing improved data fusion capabilities and a new decision-making process capable of generating (automatically or semi-automatically) multimodal response plans to events affecting corridor operations. The multimodal DSS, shown in the Decision Support System component in FIGURE G.3, or the green Network Prediction System and Real-Time Simulation System in FIGURE G.4, integrates two tools: 1) iNET—an automatic traffic management system for field device monitoring and control, center-to-center data fusion, event management and response plan generation; and 2) Aimsun Online—for real-time traffic prediction and simulation-based evaluation of incident response or congestion management strategies. When responding to an event, the DSS continues to monitor travel conditions within the corridor and issues updated recommendations when necessary, allowing the DSS to account for unforeseen changes in travel patterns or other events affecting corridor operations *in addition* to the original event.

Roles and responsibilities have been diligently defined for all agencies/entities involved (e.g., San Diego Association of Governments (SANDAG); California Department of Transportation (Caltrans); City Traffic

Divisions of San Diego, Poway, and Escondido; Metropolitan Transit System (MTS) and North County Transit District (NCTD) transit agencies; California Highway Patrol (CHP); local first responders and law enforcement, county emergency services) for the following scenarios:

- Daily operations.
- Freeway incidents.
- Arterial incidents.
- Transit incidents.
- Special event.
- Disaster response scenarios.

As shown in FIGURE G.5, San Diego stakeholders organized response “postures” around a combination of demand conditions on the network (light, moderate, or heavy) and predicted event impact (low, medium, or high). Within this framework, organized as a matrix, they then determined whether they would be likely to take “conservative,” “moderate” or “aggressive” measures to manage the impacts of an event. They coded their joint response plans accordingly.

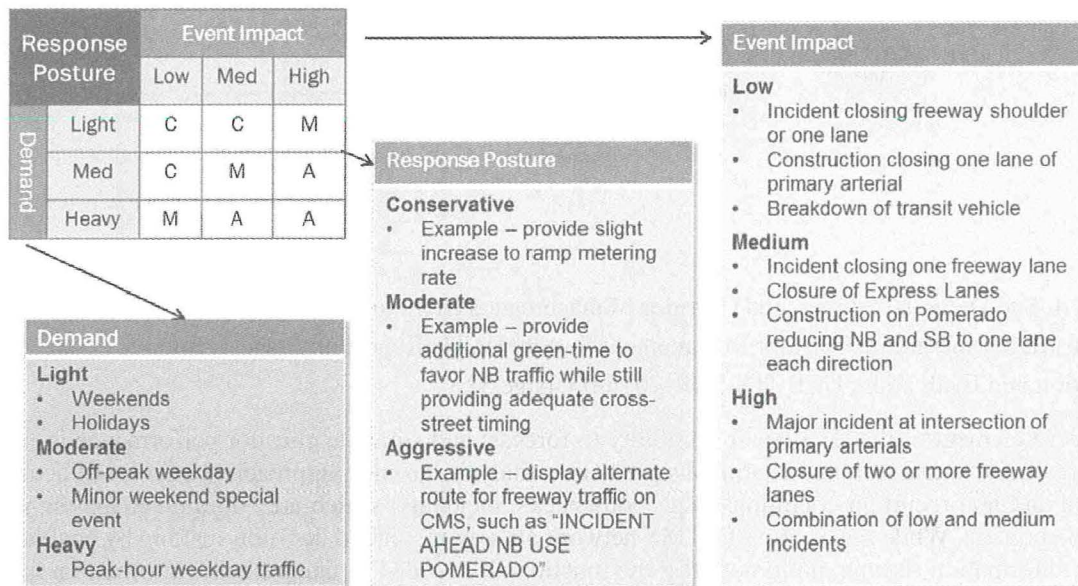


FIGURE G.5. I-15 Integrated Corridor Management response postures (San Diego Association of Governments, March 6, 2014).

The San Diego DSS is dynamic, meaning there is no “set number” of defined response plans that could be recommended by the DSS. FIGURE G.6 and FIGURE G.7 show how a combination of subsystem action plans is used to define an individual response plan based on agreed upon response posture responsiveness. Between the 156 alternate routes, 260 local arterial intersections, 18 ramp metered interchanges, 20 changeable message signs (CMS), five bus rapid transit (BRT) stations (with six extra buses in the metro area for adding transit capacity when needed), 20 miles of Express Lanes (16 miles which are reversible using a movable barrier) and 30 miles of traffic-responsive 511 within the study area, this provides enough assets that can be combined to generate *billions* of different response plans. However, the DSS is limited to recommending no more than 15 response plans at any time based on asset restrictions, availability conditions, and thresholds to select “next move” relationships. It should also be noted that response plans

rely on how quickly field elements can be changed (e.g., the stakeholders are required to have time to actually implement recommended signal timing plans). The San Diego ICMS is capable of changing response plans every five minutes, but it is not practical to change these so frequently since it takes approximately 20 minutes to evaluate and implement (out in the field) a response plan. Although the San Diego DSS implements response plans without requiring human intervention, it does have the ability for a transportation operator to object to a recommended response plan and prevent it from being implemented.

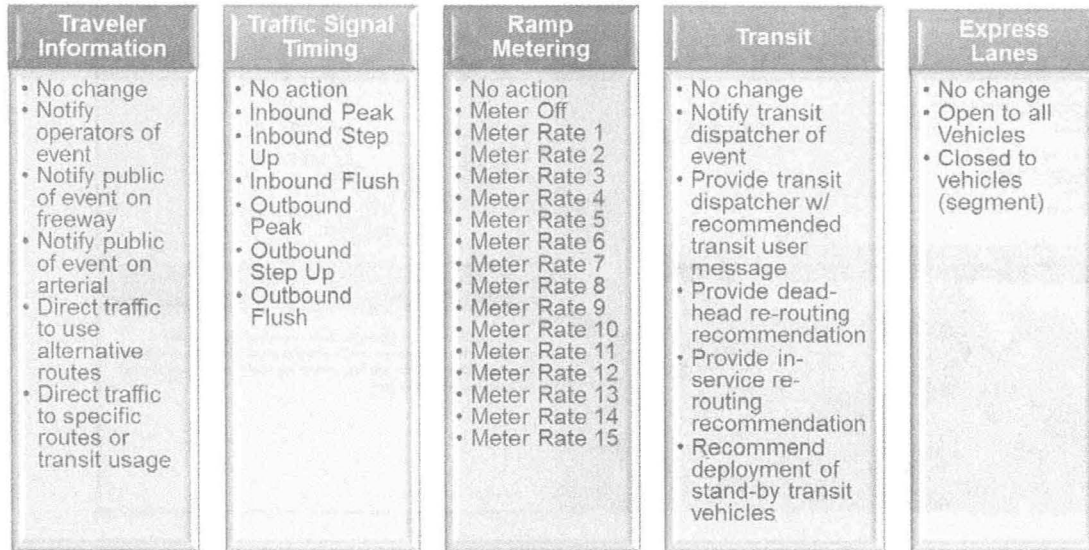


FIGURE G.6. I-15 Decision Support System-defined subsystem action plans (San Diego Association of Governments, March 6, 2014).

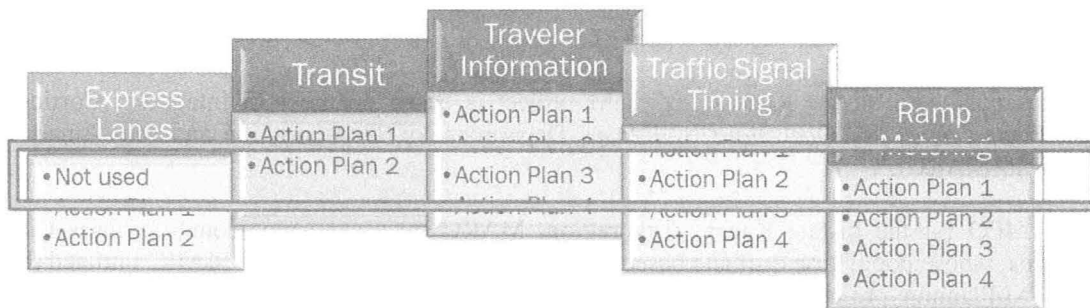


FIGURE G.7. I-15 Decision Support System multi-modal response plans (San Diego Association of Governments, March 6, 2014).

FIGURE G.8 shows an example of a response plan which was implemented at Rancho Bernardo Rd. during the northbound afternoon peak period for an event involving major congestion levels. This response plan triggered the following CMS message: "SLOWING AT // RANCHO BERNARDO // EXPECT DELAYS", ramp metering timing adjustments for two ramp meters, as well as traffic signal coordination timings for 15 signals in the cities of San Diego and Poway.

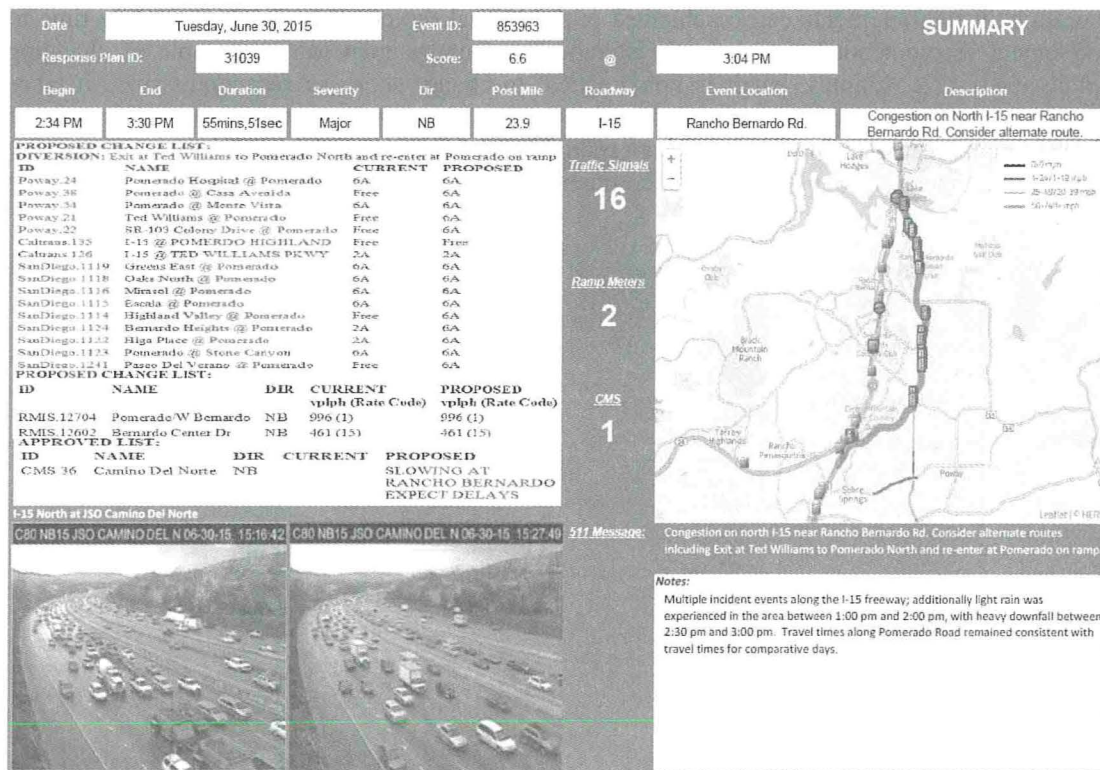


FIGURE G.8. Example response plan for northbound afternoon peak-period congestion at Rancho Bernardo Rd (I-15 ICM III—PDT Meeting #59, San Diego Association of Governments, July 15, 2015, page 28, unpublished).

Kansas (I-35) Integrated Corridor Management System

The details presented here on the Kansas I-35 ICM project is based on the I-35 Integrated Corridor Management Plan: *Concept of Operations* by Kansas Department of Transportation and Mid-America Regional Council (MARC).²¹

MARC is the MPO for the bistate Kansas City region. MARC serves the nine-county Kansas City metropolitan area, whose population estimate based on the 2010 Census is 2,086,771. MARC initiated the Interstate 35 ICM Planning project with the goal of maintaining a reliable travel time through 33 miles of the I-35 corridor in Kansas from the Sunflower Road interchange in Edgerton to the Missouri state line (see FIGURE G.9). This high traffic corridor is used by commuter traffic (major traffic generators include the Olathe Medical Center, the Garmin International headquarters, Sysco Food Services of Kansas City, the JC Penny Distribution Center, UPS and FedEx distribution facilities, etc.) and a large volume of commercial freight traffic produced by the BNSF Intermodal facility and the New Century Air Center.²²

²¹ Kansas Department of Transportation and Mid-America Regional Council. *I-35 Integrated Corridor Management Plan: Concept of Operations*. 2017. Unpublished.

²² <http://www.marc.org/Transportation/Plans-Studies/Transportation-Plans-and-Studies/Special-studies-and-projects/I-35-Integrated-Corridor-Management-Planning>.

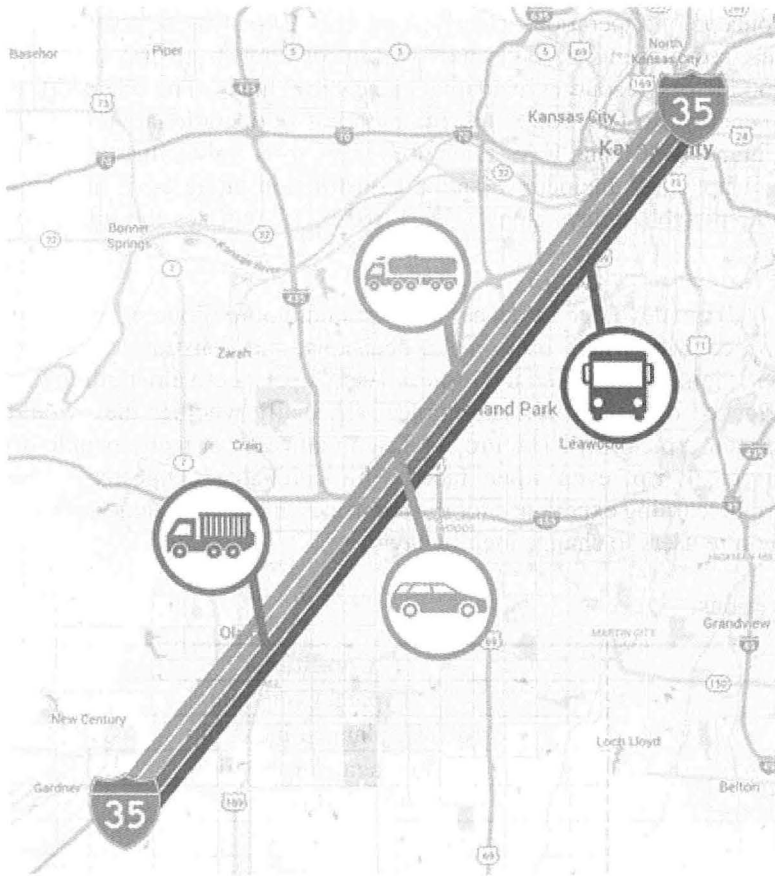


FIGURE G.9. Geographic limits of the Kansas I-35 Integrated Corridor Management project (Mid-America Regional Council).

The scope of this project is to develop a Concept of Operations (“ConOps”) for the integration of transportation modes, agencies, networks and intelligent transportation systems. The I-35 ICM Concept of Operations is a “living document” that will be regularly reviewed and maintained by a designated group of stakeholders. Following the recommended next steps will enable the development of a complete Concept of Operations for integrated operations, decision making, and continued management. While MARC’s I-35 ICM project has not yet reached the implementation phase like the more widely known Dallas U.S.-75 and San Diego I-15 ICM projects, this project is an example of efforts led by a relatively small agency with a correspondingly small constituent base.

In order to derive the appropriate ICM strategies for the I-35 corridor through the Kansas City metropolitan area, MARC’s planning approach consisted of the following steps:

1. **Scope**—Define the geographic limits for the corridor and the range of regional stakeholders to be invited to participate in Stakeholder meetings.
2. **Referenced Resources**—Documents for relevant studies and projects were reviewed by the project team. Stakeholder engagement was used to conduct a self-assessment of the Capability Maturity Model (CMM) regarding ICM readiness in the region. In addition, a System Breakdown Structure was developed for the I-35 corridor, which will be used as the base for future System Architectures and is created to accommodate any subsystem architectures such as the Regional ITS Architecture.

3. **Use Cases**—To scope the Concept of Operations clearly, one Use Case was selected to be thoroughly analyzed. The Use Case presents a single user's point of view from trip origin to destination, considering decision factors, resources available, and choices made. The selected Use Case was considered in three scenarios for four conditions for a total of 12 operational views. The scenarios are Current (2016), Future (2030), and ICM. Each of the scenarios was evaluated in four conditions: Typical Commute; Unplanned Incident; Planned Construction along I-35; and One Time Event that causes major predictable delays along I-35. TABLE G.2 outlines the full set of Use Case operational conditions.

Through this process, the Project Team developed a deeper understanding of the sources and types of information available, the speed with which users make decisions, and constraints that can influence a person's trip choices. It also enlightened the Project Team's perspective regarding key information with the most influence on a person's trip choice, especially whether they would consider diverting or adjusting their typical trip. The Project Team realized that many people do not often change from their typical trip, even when faced with unreliable congested travel experiences. This was an important learning experience for the team, as some ICM techniques used to improve system reliability require users to change their behavior.

TABLE G.2. Use case operational conditions.

Scenarios	Conditions
Current (2016)	Typical Commute
	Unplanned Incident
	Planned Construction
	One-Time Event
Future (2030)	Typical
	Unplanned Incident
	Planned Construction
	One-Time Event
ICM	Typical
	Unplanned Incident
	Planned Construction
	One-Time Event

Source: Mid-America Regional Council.

4. **User and Operational Needs**—User Needs (top level needs that the system shall fulfill to meet its intended purpose) and Operational Needs (derived from the User Needs and directly relate to the ICM activities that shall fulfill the User Needs) were derived from the Current and Future Use Cases developed for this project. These needs are a result of the Use Case evaluated in its defined Scenarios and Conditions. While these needs are widely applicable to the I-35 corridor, other needs may not be represented, such as freight movement. A clear next step for the development of ICM in the region would include additional analysis of Use Cases to complete the User and subsequent Operational Needs of the ICM system.

The User Needs listed in TABLE G.3 describe the expectations of the transportation system, while the Operational Needs in TABLE G.4. describe the expectations of the ICM system and regional processes.

TABLE G.3. User needs.

ID #	Title	Rationale/Description
UN1	Pre-departure information on travel options	Transportation system users often make travel decisions before beginning a trip. Therefore, the transportation system should provide real-time, accurate information upon which users can know and compare travel options to make informed decisions before beginning their trip.
UN2	En-route information on incidents or delays	Travelers en-route can adjust their travel plans en-route if equipped with real-time, accurate system information. Therefore, the transportation system should provide real-time, accurate information upon which users can know and compare travel options to make informed decisions while en-route.
UN3	Accurate decision input	Travelers do not always trust the published travel information. Therefore, the transportation Corridor Managers should place a priority on providing timely, accurate information to the public for decision making.
UN4	Access to multimodal options	Multimodal transportation options are not always at the forefront of transportation system user's minds. To enhance the knowledge and accessibility of multimodal options, the transportation Corridor Managers will work together across modal boundaries to provide a complete transportation service.
UN5	Reliable travel times—highway	Travel time reliability is an important factor for highway users. The transportation Corridor Managers will work together to actively manage highway system reliability by providing coordinated incident responses, proactive event management, and coordination with other system service managers.
UN6	Reliable travel—arterial	Travel time reliability is an important factor for arterial users. The transportation Corridor Managers will work together to actively manage arterial system reliability by providing coordinated incident responses, proactive event management, and coordination with other system service managers.
UN7	Reliable travel times—transit	Travel time reliability is an important factor for transit users. The transportation Corridor Managers will work together to actively manage transit system reliability by providing coordinated incident responses, proactive event management, and coordination with other system service managers.
UN8	Knowledge and support of travel demand management options	Travel demand management options can be powerful, cost-effective tools for travelers to avoid congested travel and support a resilient transportation system that can respond in real-time. The transportation Corridor Managers will work with regional economic entities, media connections, and others to inform, encourage, and support travel demand management options.

Source: Mid-America Regional Council.

Note: Text in blue must be evaluated for inclusion in I-35 ICM concept. These items were either not specifically addressed in the project development process or vetted with the system owner.

TABLE G.4. Operational needs.

ID #	Driving User Need		Description/Rationale
	ID #	Title	
ON1	UN1	Publish	Information produced by the ICM System (ICMS) and its subsystems will be provided to system data users in a variety of data formats for travelers to use to make decisions and take actions based on real-time information.
	UN2	Information to System Users	
ON2	UN1	Publish	Information produced by ICMS and its subsystems will be provided to system data users (aka 3rd Party providers) in a variety of data formats to display information for travelers to use to make decisions and take actions based on real-time information.
	UN2	Information to Third-Party Providers	
ON3	UN3	Collect and Process Data	Data is collected from a variety of existing and planned systems that support system reporting and synthesize decision input information. A central data processing manager should be identified (could be KC Scout or MARC). These data locations and process methods are documented in Interface Control Documents, which need to be developed for existing systems and new systems as they come on line. Algorithms are needed to aggregate the data into corridor level reporting structures for the selected measures (e.g., volumes, occupancies, and speeds at multiple locations are converted to travel times). Process Data includes conversion of host system data formats, if necessary, to standard XML schema for publishing information to share across the ICMS system.
ON4	UN3	Access and Store Historical Data	Provide the capability to create, populate, and access a historical database that includes existing independent data and future available data to create a variety of reports on corridor operations and performance. This database should contain real-time information on corridor performance as derived from data collected under Collect and Process Data. Accessing existing historical database of KC Scout is an important function of this Operational Need. Consistent export formats for data from these historical databases would simplify corridor-wide analysis. Ad hoc reporting based on this historical data allows the system users to create a variety of reports that characterize corridor operations and performance. These reports can then be stored in the historical database.
ON5	UN3	Predict Future Travel Conditions	Provide the ability to use historical data fused with current data to predict the impact of travel conditions and incidents and predict the routing choices of system users. The predictions will then be used by Corridor Managers to adjust system operations as needed to respond to predictions. This system will be revisited annually to recalibrate prediction algorithms. This system will provide input to the decision support systems.
ON6	UN3	Publish Information to Corridor Managers	Information produced by ICMS and its subsystems will display in a variety of data formats to agency decision makers for use to visualize corridor operations, make decisions, and take actions to implement the various decision components.
ON7	UN3	Coordinate Incident Responses	Corridor Managers and ICM stakeholders develop potential response plans to respond to incidents that occur in locations with historically documented high incident rates. Response plans are based on the prediction of likely diversion routes and define a coordinated response by Corridor Managers.

Driving User Need			
ID #	ID #	Title	Description/Rationale
ON8	UN4	Access to multimodal options	Provide tools for regional awareness of multimodal options, including last mile connections from transit. This would include the Transportation Hubs under development through the Ride KC effort, and third-party transportation services such as ZipCars, Uber Share, and B-Cycle facilities. The goal of this need is to broaden awareness of the suite of transportation options in the region, so travelers can have confidence that if they begin a trip outside of their personal vehicle they will be able to complete a round trip.
ON9	UN5, UN6, UN7	Coordinate Public Safety and Transportation Operations	Provide public safety professionals access to the multi-dimensional data inherent in transportation management systems while seeking technical solutions to extracting useful incident information from public safety Computer Aided Dispatch systems. Useful incident information can be used by Corridor Managers to identify problem areas and ways the first responders can be better supported to quickly respond and clear incidents.
ON10	UN5, UN6, UN7	Interactively Conference with Corridor Agencies	Corridor Managers will directly collaborate in real-time prior to, during, or after a major event in the Corridor. This will enable real-time decision making and consistent situational awareness as an event develops. A variety of voice, video and data formats will be supported for multi-site collaboration.
ON11	UN5, UN6, UN7	Implement Incident Responses	The Response Plan allows ICMS and Corridor Managers to use a decision tool (Expert System or table-driven) that fuses real-time data and manually entered data to determine if an incident response plan trigger has been met. Manually entered data can include that coming from the event site (e.g., KHP Traffic Officers talking to dispatchers using the KHP radio system). The response plan is then either manually or automatically generated based on the fused data input. Once a response plan is generated, the system operator can review the plan's components and make changes deemed necessary before transmitting plan components to the affected systems. The status of affected systems is then returned to the ICMS operator and logged in the historical database.
ON12	UN5, UN6, UN7	Share Control of Devices	Allow agencies to control selected functions of field devices remotely regardless of location or agency ownership. This will allow agencies to implement response plans and support system reliability. For this Operational Need to become real there must be interagency agreements to allow such sharing under carefully defined conditions.
ON13	UN5	Reliable travel times—highway	Measure and control highway travel time reliability by reporting reliability measures, evaluating the system performance, and adjusting corridor operations plans to maximize system reliability.
ON14	UN6	Reliable travel times—arterial	Measure and control arterial travel time reliability by reporting reliability measures, evaluating the system performance, and adjusting corridor operations plans to maximize system reliability.
ON15	UN7	Reliable travel times—transit	Measure and control transit travel time reliability by reporting reliability measures, evaluating the system performance, and adjusting corridor operations plans to maximize system reliability.
ON16	UN8	Knowledge and support of travel demand management options	Provide tools for regional awareness of travel demand management options. Target audiences for these would be economic development agencies, chambers of commerce, elected officials, and regional planners. Tools may include comprehensive recommendations such as creating a Transportation Management Association (TMA) or simply offering flexible work hours. Corridor Managers' role in this

Driving User Need ID #	ID #	Title	Description/Rationale
			is to provide accurate and timely information on available transportation systems, their performance, and peak congestion times and days so people can adjust their travel patterns.

Source: Mid-America Regional Council.

Note: Text in blue must be evaluated for inclusion in I-35 ICM concept. These items were either not specifically addressed in the project development process or vetted with the system owner.

5. **Goals for I-35 Integrated Corridor Management**—Based on the User and Operational Needs defined above, the following goals were developed for the I-35 ICM:

- Actively manage the corridor to provide reliable travel times for users.
- Coordinate jurisdictional and modal responses to recurrent and non-recurrent congestion.
- Actively broaden awareness of multimodal options and ways to reduce demand on our transportation system.

6. **Concepts for the Proposed System**—Based on the Operational Needs defined above, a set of over 50 ICM strategies was developed. These strategies were evaluated, synthesized, and refined into 11 thematic groups. The 11 groups of strategies were presented to the corridor Stakeholders for prioritization. Priorities of 1, 2, and 3 were used to group the strategies. Priority 1 are strategies that can be implemented within three years. Priority 2 are strategies that can be implemented within three to five years. Priority 3 are strategies that can be implemented in five years or longer. TABLE G.5 lists the final 11 recommended ICM strategies, narrowed down from the complete list of potential ICM strategies identified for I-35.

These strategies will continue the development of ICM in the corridor and will enable continued development of the Operational Concept. These strategies are not the final comprehensive list of strategies needed for complete implementation of ICM along the I-35 corridor, but they offer a path of active steps forward.

TABLE G.5. Recommended Integrated Corridor Management strategies.

Strategy #	Priority	Topic Area	Theme	ICM Initiatives and Strategies	Operational Needs Addressed
1	1	Institutional	Travel Demand Management	Encourage Telecommuting, Delayed Commuting, and Flex Time for Employers and Workers using the I-35 Corridor.	ON13, ON14, ON15, ON16
2	1	Institutional	Travel Demand Management	Media Support of Creative Commuting.	ON16
3	1	Institutional	TSMO Committee	Create an ICM/TSMO Committee within MARC.	ON9, ON10
4	1	Institutional	TSMO Committee	Intensify Traffic Incident Management (TIM) Activities on the I-35 Corridor.	ON7, ON9
5	1	Technical Integration	Multi-Modal	Develop Mobility Hubs along the I-35 Corridor.	ON8, ON10, ON16

Strategy #	Priority	Topic Area	Theme	ICM Initiatives and Strategies	Operational Needs Addressed
6	1	Operational	Arterial Integration	Enhancement of the Operation Green Light Program in Kansas City.	ON2, ON3, ON5, ON10, ON11, ON12, ON14
7	2	Technical Integration	Multi-Modal	All-Inclusive Transportation Dashboard.	ON1, ON3, ON5, ON16
8	2	Technical Integration	Transitional Technology	Facilitate the Deployment of Connected Vehicles and Vehicle to Infrastructure Systems.	ON2, ON3, ON4, ON10
9	2	Technical Integration	Transitional Technology	Prepare the I-35 Corridor for the Technology Shift to Autonomous Vehicles.	ON2, ON3, ON4, ON10
10	3	Operational	Arterial Integration	Expand the use of DMS on arterials adjacent to I-35.	ON1, ON9, ON10
11	3	Operational	Managed Lanes	Implement Dynamic Lanes/Managed Lanes on I-35.	ON13

Source: Mid-America Regional Council.

7. **Implementing Recommended ICM Strategies**—For each of these recommended ICM strategies, high-level roles and responsibilities have been assigned to transportation system managers (e.g., MARC, Kansas Department of Transportation, Kansas Highway Patrol, Missouri Department of Transportation, Kansas City Scout, Operation Green Light, and Kansas City Area Transportation Authority), and next steps to begin implementation of the strategy have been detailed.

Institutional, Organizational, and Technical Arrangements

This appendix describes a set of critical arrangements among ICM stakeholders, travelers, and operators required to realize a successful ICM deployment. These include both technical and non-technical arrangements developed for an ICM initial state adapted over time as the deployed system is refined and improved (see the discussion in Appendix E regarding ICM as a continuous improvement process). This appendix is primarily a discussion of the breadth and type of arrangements themselves and how they can be effectively maintained and enhanced over time; for strategies on engaging stakeholders to develop an initial set of charter arrangements, the reader should refer to the ICM Guidebook.

Managing a dynamic corridor effectively requires an equally dynamic management of arrangements among ICM system stakeholders. ICM solutions are often deployed in highly complex and dynamic transportation corridors. These complex transportation corridors have an equally complex set of stakeholders that include freight, transit, incident response, and non-traditional (pedestrian/bike) stakeholders. Successful ICM deployments over time must recognize that just as the tangible corridor assets made of concrete, asphalt, steel and silicon must be maintained and sometimes refreshed or replaced—the arrangements binding stakeholders together must also be maintained and sometimes refreshed or replaced. As user needs and technology change, how the ICM is conceptualized, defined, operated, and financed among stakeholders must change in response. The arrangements enabling the ICM system to function must also include mechanisms so these arrangements can be adapted over time. The documents describing the shared vision, roles, responsibilities, and tactical arrangements made among the ICM system stakeholders—the *institutional capital* of the ICM system -- are arguably the most critical ICM assets to ensure long-term cohesion among stakeholders and long-term viability of the ICM deployment.

If an ICM system is deployed as a static build-and-forget solution, it may soon become ineffective, irrelevant, and eventually abandoned in favor of other more relevant solutions aligned with current issues and concerns. Technical, organizational, and institutional arrangements are bringing together ICM stakeholders to periodically reexamine corridor performance, emerging threats/issues, underlying changes in corridor traveler/user needs and demand patterns, ICM system capabilities, and the potential of emerging technologies. These periodic assessments should begin with challenging the previous purpose and nature of the ICM system, assess the capability of the ICM to meet performance goals, and make plans to refine/replace unsatisfactory aspects of the ICM system.

This appendix has three sub-sections: The first sub-section provides a detailed examination of the arrangements among ICM stakeholders, including examples specifically targeting considerations of freight, transit, incident response and pedestrian/bike stakeholders. The arrangements are presented according to the following classification:

- *Institutional arrangements*, governing how ICM stakeholders determine and guide the strategic direction of the ICM deployment over time—including geographic boundaries, scope of actions, financial plan, stakeholder engagement/retention and institutional form.

- *Organizational or operational arrangements*, governing the roles, responsibilities, limitations, and tactical interactions among ICM system operators engaged in real-time day-to-day decision-making within the corridor.
- *Technical arrangements*, governing the ownership and responsibility among stakeholders for the security, monitoring, maintenance, and enhancements of ICM system assets (both tangible and intangible).

The second sub-section provides a structured exercise for ICM stakeholders to assess the maturity of the existing ICM institutional capital and to identify the most likely technical, organizational, and institutional arrangements to either create or enhance the system.

The third sub-section provides a high-level summary of prototypical organizational frameworks among ICM system stakeholders spanning a range of more ad hoc and informal forms to more formal and systematic structures. Each of the individual frameworks are provided in additional detail in Appendix I. The maturity assessment described in the second sub-section is reused to examine the pros and cons of adapting to a new organizational form as the demands on the ICM system change over time.

Institutional Arrangements

Institutional arrangements (see FIGURE H.1) govern how ICM stakeholders guide the strategic direction of the ICM deployment over time—including geographic boundaries, scope of actions, financial plan, stakeholder roster, and institutional form.

These arrangements focus on strategic ownership and delegation of responsibilities for the ICM system. It includes a discussion of what kinds of access and control partners have, and broad decisions to integrate several separate systems in a decentralized manner, or to take a more centralized approach. Each approach has benefits and drawbacks, so arrangements must be aligned with the technical and non-technical maturity of the current ICM system and its stakeholder partners.

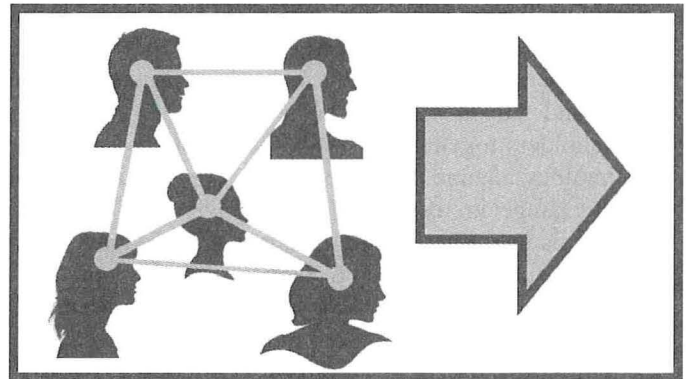


FIGURE H.1. Institutional arrangements.

It is important to define limits and boundaries for what an ICM system should cover (and not cover) and the nature of the actions it will take (and not take). For example, ICM is often deployed as a combination of applications and strategies specifically targeting non-recurrent congestion conditions associated with major incidents, special events, and severe weather. In these cases, the ICM system may be tightly, loosely, or simply not connected with specific stakeholders, transportation modes, information channels, or facilities (e.g., signal systems at critical junctions with pedestrian/bike routes, parking or tolling policies, and dynamic transit dispatching). Every ICM system depends on the capabilities of the participating organizations—and an appropriate shared vision of these organizations to provide and maintain assets, share data, and take coordinated actions.

At the inception of the ICM effort, it may not be clear among stakeholders the nature and capabilities of each stakeholder organization—and some time may need to be set aside so that this shared level of understanding matures prior to making key decisions regarding scope, financial relationships, and

organizational form. While more elaborate visions of an end-state ICM are useful to provide motivation for stakeholder engagement and a collective sense of ultimate destination, near-term institutional arrangements are required dependent on a realistic assessment of what each ICM partner can provide in terms of people, assets, and capabilities. For example, intersection pedestrian detection systems may need upgrading to accommodate ICM strategies for special events, or additional transit staff may need to be trained to operate under special event policies tailored to absorb a predicted surge of pedestrian demand. New corridor-focused roles may need to be created outside of existing partner organizational structures and a process to identify and staff these positions may need to be put in place.

Institutional arrangements include maintaining the ICM system scope, vision and goals over time; arrangements describing the scope, nature and duration of ICM system integration; financial and capital planning arrangements; and agreements covering organizational forms and governance policy.

The type, number, and complexity of institutional arrangements are highly dependent on the organizational form/framework used by the ICM stakeholders. These organizational forms range from *ad hoc* informal arrangements at one end of the spectrum to formal models where roles and responsibilities are clearly defined. Appendix I provides six example frameworks that follow this spectrum from least to most formal. In general, the type, number, and complexity of institutional arrangements grow proportionally with the amount of formal structure inherent in the overarching organizational framework. A risk to any developing ICM concept is balancing documented arrangements with the current and forecasted needs of the ICM stakeholders. Too few or vaguely documented arrangements will deter the development of more robust, effective, integrated ICM solutions. Burdening an emerging ICM solution with too many or needlessly complex arrangements may slow progress towards initial successes needed to create momentum. In these cases, a lightweight approach to formal arrangements may serve the ICM stakeholder community well for several years as the ICM solution develops from an early to a more advanced state.

Corridor Vision, Goals, and Integrated Corridor Management Concept Management Arrangements

These arrangements document the most fundamental of ICM concepts: What is the corridor? How is it defined? What are the shared goals and vision of the ICM stakeholders? How is the ICM concept organized among partners? These arrangements can be as informal as short statements of shared vision and goals that are non-binding but demonstrate an intent to cooperate—often critical in gaining early momentum to bring stakeholders to the table. At the more complex end of the spectrum, these arrangements can be formal agreements that define roles, allocate responsibilities, and codify leadership arrangements among stakeholders to support ICM solutions over time.

This kind of institutional arrangement is nearly always needed in some form (or even multiple forms). Lack of formal agreements early in the process can lead to delays in implementation as differences in understanding and clarifications in shared expectations were worked out “on the fly.” Most critically, these arrangements should include the capability for the periodic adaptation of these arrangements. Otherwise, they can quickly become stale and outmoded—or simply forgotten as individuals change positions.

- **Vision and Goals.** These early documents should cover key items such as corridor boundaries, scope, goals, performance measures, as well as a list of participating/observing organizations. Early vision statements, charters, MOUs and other organizational documents set the stage for more detailed documentation and support the eventual development of a corridor management Concept of Operations (ConOps).
- **Setting Early Limits/Focus.** Caltrans has four Connected Corridor projects, and each of them has a different area of emphasis. One corridor concept was defined to focus only on non-recurrent

congestion, after engaging neighboring jurisdictions regarding freeway-to-local street traffic diversion. Another corridor in California will focus initially on a single ICM strategy, adaptive ramp metering, as a first step towards more comprehensive corridor management in the future. The Dallas I-75 ICM solution restricted operational hours from 6 AM to 6 PM—as the need for active corridor management was not cost effective outside of this period.

Example(s)/Insights: New Stakeholders? Hit the ICM Conceptual Restart Button. When an ICM concept is expanded to include new stakeholders (e.g., freight, transit, ped/bike, or incident management), a key first step is to reconsider existing vision, goals, and focus of the ICM system. Failure to do so means creating a second tier of latecomer stakeholders who will by default have a lower level of buy-in.

System Integration Arrangements

These arrangements document the high-level agreements among stakeholders regarding roles, responsibilities, and shared actions. Under specific conditions (e.g., an incident in location X), or a class of conditions (e.g., an incident anywhere in the corridor), there is a corresponding breakdown of key stakeholders, actions to be taken (and not taken), and the desired level of joint control. For example, in response to a major incident, stakeholders may agree to coordinate tactical actions by staff at the direction of a lead law enforcement agency. At the strategic level (away from direct proximity to the incident), stakeholders may agree to much more operational leeway to disseminate information or take mitigating actions (e.g., transit rerouting). The level of coordinated action, and the technical capability of the system to implement this are best documented in operational and technical arrangements. However, the level of system integration at a higher level is best documented in institutional arrangements that set the limits and guide development of more detailed organizational and technical arrangements.

These arrangements can be combined with higher-level vision and goal statements to articulate a more detailed description of the level of integration that will be realized in an ICM deployment (initially or incrementally). A longer-term vision of full integration can still be useful as an end-state goal. However, jumping directly into such arrangements can be risky. Creating these arrangements and updating them can be useful in setting limits to the systems engineering process so that the system designed reflects the level of integration that the stakeholders are willing to put into operational practice and design of the deployed systems. A lack of these types of arrangements can lead to a game-time realization that a system has been designed (or even built) but includes a level of operational and technical integration that key stakeholders may not find acceptable. These arrangements are also useful for setting senior management expectations within larger stakeholder organizations, groups of competing stakeholders (e.g., freight operators), and other stakeholders. These arrangements ensure the intended nature of coordinated action and/or system integration is clearly explained and provides an inherent justification for the level of system integration chosen.

- **Key Features.** Define the scope, nature, and duration of system integration among coordinating ICM sub-systems. Are there special cases under which different rules should apply?
- **Finding a Comfort Zone Between Parallel Play and Integrated Operations.** Effective corridor management may not require a high level of integration everywhere and under all conditions. In some modes of operation, a general set of guidelines that shares likely responses and a willingness to communicate among stakeholders regarding actions taken can be highly cost effective. As trust is built up and the effectiveness of collaborative corridor management is observed, the locations and times where more integrated solutions are required can be identified. When this happens, the system integration arrangements can be updated to reflect the agreement among stakeholders as well as the identified need that motivated the update. Without this documentation, a change in leadership in one stakeholder group may unnecessarily result in a retreat from what had been

previously agreed to—simply because there was no documentation to substantiate the agreement reached with prior stakeholder leadership.

Example(s)/Insights: Special Considerations for Incident Management Stakeholders. Given that some aspects of incident response will include law enforcement activity, there may be a strong rationale to keep specific elements of those activities separate from corridor management actions. Incorporating language on where corridor management activities end and law enforcement activities begin can reduce confusion regarding roles and allowable actions.

Financial and Capital Planning Arrangements

These arrangements document the agreements among stakeholders regarding ICM-specific business relationships among stakeholders, including the sources of funding for system operation, maintenance, and enhancement. These enhancements may include capital purchases.

Stakeholders may be initially leery of financial arrangements in the early stages of ICM concept development. However, these considerations will be a significant element in a move to the intermediate Coordinated Operations framework model or any of the advanced frameworks documented in Appendix I. Lack of financial and capital planning arrangements can be problematic if there are joint purchases of capital equipment, shared operational costs, or compensated corridor-focused staff positions.

- **ICM Business Planning.** This type of arrangement documents the ICM business plan. This plan documents who contributes (in terms of staffing, equipment, and/or paying for operational costs) and the benefits that accrue to each of the partners. Not all contributions or benefits need to be quantified and monetized in such an analysis. It can be helpful for all stakeholders to create a give/take diagram showing the shared costs and benefits of the ICM solution. This diagram can be used to inform stakeholders who may have an inflated sense of their own (or own organization's) contributions and little understanding of the costs borne by other stakeholders.
- **Mine, Theirs and Ours Capital Planning.** There is a need to coordinate capital planning among diverse corridor stakeholders since each organization has its own annual or multiyear cycle planning. There is often offset among the stakeholders' cycles and it can be difficult to mount a large coordinated capital purchasing effort. Arrangements that document the capital expenditures planned over time can help to lock in commitments to follow through according to that plan. One of the benefits of external funding is that capital timing among stakeholders can be linked to grant awards—but even in these cases, how this corridor capital is allocated among stakeholders must be documented. There may be costs to procure as well as operational and maintenance costs -- and the capital purchases must have a clear owner/purchaser. Capital expenses and allocation among stakeholders should be incorporated into ICM business planning.
- **End-State Financial Planning.** Particularly in the case where external or ICM grant funding helps to initiate an ICM concept, there is a tendency to avoid or put off thinking about long-term financial sustainability. ICM grant funding is nearly always a one-time resource infusion. Stakeholders should plan (and document) the longer-term contributions and benefits as a part of the give/take diagram showing a stable end-state for the ICM solution. Otherwise, stakeholders may be forced to come up with improvisational operations and maintenance funding—funding which can be difficult to obtain on the fly but may be locked in by agreement when these arrangements are put in place.

Example(s)/Insights: CV Pilot Financial Sustainability Planning. The Connected Vehicle (CV) Pilot Deployment Program required each deployer to complete and document financial sustainability for a post-deployment grant period of at least five years. The responses include innovations in non-traditional revenue sources (e.g., toll revenues in the Tampa deployment), and documentation of the expected contributions from all stakeholders to meet the five-year sustainability requirement.

For more information, please see: <https://www.its.dot.gov/pilots/>

Organizational Forms and Governance Policy Arrangements

These arrangements document the agreements among stakeholders regarding how to organize themselves and the governance policies put in place to adapt or amend these arrangements over time. A collection of example frameworks is provided in Appendix I and discussed in additional detail with respect to corridor maturity later in this appendix. The general nature and content of these arrangements are presented in this sub-section.

Often the first document of this type comes in the form of a charter, which often comprises a statement of shared vision and goals, a stakeholder roster, and an organizational framework. This may designate a lead agency or organization, or establish a more consensus-driven model. The organizational form will almost certainly need to be adapted over time, so a key element to include in any arrangement of this type are the rules all the stakeholders agree to when it is time to amend or adapt the current arrangement.

Key topics that these arrangements document include:

- **Regular Meetings and Rules of Order.** Virtual or in-person, periodic meetings among stakeholders are needed to provide organizational cohesion and provide timely adaptations to organizational form when needed. Early state deployments require more frequent meetings (quarterly, monthly, or biweekly), while intermediate and advanced deployments may need to meet less frequently (quarterly, semiannually, or annually).
- **Stakeholder Roster Changes.** A clear mechanism for managing roster changes when new partners join, old partners change roles, or partners are unable to continue is critical. There may be many changes in an early-state ICM deployment.
- **Ongoing Commitment Requirements.** Provisions for requiring ongoing commitment and participation to ICM for successful operation (i.e., protections for the common investment), as well as provisions for leaving the ICM commitment if it becomes infeasible for the stakeholder to continue participating (i.e., protections for the individual stakeholders). Tiered engagements, e.g., lead/associate/observer organizations, can also be considered.
- **Disputes.** This element describes how disagreements among stakeholders are resolved. In some cases, a special study can be commissioned to ensure that all parties are working from a similar set of shared facts (see below).
- **Amendments.** Mechanisms for adapting, changing, and scoping organizational forms (e.g., charter amendments) should be included in even the earliest forms of these arrangements.

Example(s)/Insights:

- **Special Studies.** One way to resolve perceived inequities in operational practice is to conduct a special study to assess benefit/disbenefit distribution. For example, a simulation study could assess

what would happen if ramp meter adjustments were included or not included in an ICM response. This would give insight into the impacts of excluding certain systems, either qualitatively or quantitatively—by facility or stakeholder group.

- **Minimum Thresholds for Participation.** A short checklist of minimum requirements expected of all ICM organizational members can be useful to clarify and maintain commitment. These may be as simple as following through on hosting of and participation in periodic stakeholder events/meetings—and abiding by all documented agreements.

Organizational (Operational) Arrangements

Organizational or operational arrangements (see FIGURE H.2) govern the roles, responsibilities, limitations, and tactical interactions among ICM system operators engaged in real-time day-to-day decision-making within the corridor.

Examples include common procedural arrangements for ICM (e.g., whether a set of actions will be selected based on an automated system following an optimization algorithm, or according to a predetermined list of increasingly severe strategy responses, or some other method).

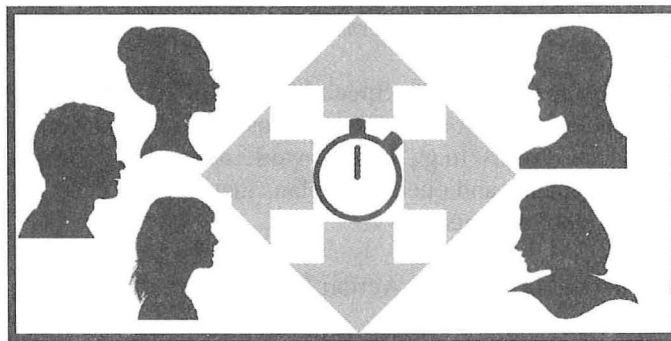


FIGURE H.2. Organizational (operational) arrangements.

ICM system development following a systems engineering process will describe and develop detail associated with many of these procedures. In this case, the arrangements can either directly reference the systems engineering documentation or alternatively, operational practices and processes can be extracted to create new organizational arrangements. When the systems engineering documentation is comprehensive and maintained in an updated format, arrangements that reference these documents have the advantage of not having to keep two parallel sets of documents consistently updated.

Operational Mode and Procedures Arrangements

These arrangements document the agreements among stakeholders that establish the fundamental ground rules under which operational coordination will be carried out. These must be consistent with the roles and responsibilities laid out in the institutional arrangements (e.g., Concept Management and System Integration) and supported by the technical capabilities set forth in complementary technical arrangements. Without these arrangements in place, it may be difficult to coordinate effectively without a common understanding of system status and defined roles. A set of early operational mode and procedures arrangements may not always be highly detailed but should cover fundamental aspects such as

- **Operational Roles and Responsibilities.** These arrangements lay out which stakeholders take on roles within operations and defines the extent and limit of their responsibilities.
- **Modes of Operation.** These arrangements may be as simple as describing a normal, active mode versus a mode in which the ICM system is not functioning. In practice, these modes are expanded incrementally to include the specific modes under which a distinct set of tactical operations will take place (see tactical operations action planning below). This description should also identify

sequencing among modes of operation, that is, it may not be possible to move directly from one mode to another without first passing through an intermediate mode.

- **Diagnostics and Monitoring.** One key role for stakeholders includes observing both system performance and corridor operational conditions. Diagnostics refers to tracking the system itself to ensure the ICM capability is running as designed without error. Monitoring refers to the tracking of corridor performance and status, e.g., surveillance for incidents within the system. Changes in either a diagnostic state or corridor condition may trigger a change in operational mode.
- **Restart and Recovery Procedures.** The ICM solution may be turned off at certain times of day or week and then restarted for peak periods. Some subsystems may be acted upon independently, and how the subsystems and systems restart from an inactive model can be documented—including the step-by-step operational roles taken by individual stakeholders.

Example(s)/Insights: Special Event/Incident Response Modes of Operation. Examples include general response modes, roles, and actions taken for incident management and the broad roles taken for annual special events (e.g., bike-to-work day). The CV Pilot deployment sites have documented a set of maintenance and operations plans that serve to describe and coordinate general modes and procedures for their deployments.

Tactical Operations Action Planning Arrangements

These arrangements document the agreements among stakeholders regarding the tactical roles, responsibilities and actions to be taken in response to varying operational conditions within the corridor. These tactical plans are the heart of the ICM playbook and response plans documented in Step 7 of the Guidebook. These arrangements will typically grow in number and detail as the ICM deployment matures and takes on more complex corridor management strategies. Without such arrangements, it may be difficult to effectively manage and coordinate corridor management actions.

Specifically, these arrangements spell out the specific roles, responsibilities and sequence of actions taken in response to observed conditions in the corridor. Rather than working from a general set of principles driving coordination among stakeholders at a broad level, these arrangements set forth specific response plans that stakeholders formulate together and agree to follow.

- **Tactical Planning and Execution.** Some responses require a detailed coordinated response. For example, a corridor ICM system may include some subelements where freight signal priority is required to assist on-time delivery at key intermodal facilities. Access to these facilities may run counter to optimal transit signal priority timing, bike lane access, pedestrian movements, and other considerations. In order to implement coordination among these competing corridor demands, detailed intersection and facility plans may be needed—far beyond informal coordination among the jurisdictions controlling the signals and the collection of stakeholders. A key element of these plans includes limiting and defining levels of authority for each stakeholder.
- **Playbook Approaches.** In complex corridors, the number of plays needed in a playbook may be large. A detailed plan may be created for a situation that occurs infrequently (or never again). At the same time, operational conditions that warrant coordinated action but are not in the playbook may be numerous. At some point, a detailed playbook may need to be replaced with a more flexible set of rules that describe general actions to be taken supported by a set of automated adaptations. Whether such a system is needed depends on the repeatability and classification of the operational conditions experienced in the corridor—and the nature of the required corridor management response.

Example(s)/Insights: Dallas and San Diego Examples. Dallas ICM playbook example, U.S.-75 optimization combined with DSS (see Appendix G)

Safety/Emergency Management Arrangements

These arrangements document the agreements among stakeholders regarding unplanned safety or emergency conditions within the corridor. These are not general incident response plans as might be included as part of an ICM Playbook. Rather these are the arrangements made for the safety-focused scenarios within the corridor. For a freight corridor, this might be related to severe weather events or the breakdown in communications among safety-critical infrastructure elements such as variable speed limit equipment. Without such plans, the ability to respond rapidly and effectively to safety-critical scenarios may be limited.

- **Safety Scenario Planning.** This depends on the corridor but such arrangements are reserved for rare events not considered within operational conditions analysis. These may include power failure, extreme weather, unpredictable natural forces, earthquakes, wildfires, or mudslides.
- **Rapid Response Teams.** Roles and responsibilities among stakeholders may need to be radically overhauled from the more day-to-day operational roles. This may include establishing rapid-response teams, or processes to convene key leadership quickly to make decisions. A depth-chart approach may be useful in case individuals are not immediately available to respond.

Example(s)/Insights:

- **Special Considerations for Freight Stakeholders.** From the WYDOT CV Pilot Deployment Safety Management Plan https://www.its.dot.gov/pilots/cv_pubs.htm abstract: *The document is presented based on identifying the safety scenarios at both system-level and application level, assessing the level of risk for each scenario, and providing a safety operational concept for high/medium-risk scenarios. Safety stakeholders were identified, existing safety plans were reviewed, and coordination with emergency responders was incorporated in the Safety Management Plan. The Pilot Deployment team identified and analyzed 14 potential hazard events.*
- **Special Considerations for Transit Stakeholders.** Transit agencies often have formalized emergency planning arrangements for their systems related to fire, technical failure, or criminal/terrorist action. A corridor-wide plan can sometimes get its start from building up from these plans—however, note that the corridor plan should be viewed as comprehensive from the emergency source (occurring anywhere in the corridor) rather than just a corridor-level response to transit system emergency operations.

External Stakeholder Engagement Protocols/Procedures Arrangements

These arrangements document the agreements among stakeholders regarding how to communicate with the press, the public, and other stakeholders. Who is authorized to speak for the corridor? Under what conditions should stakeholders communicate with external stakeholders? Without such plans, the ability to provide a common message may be limited.

- **Methods of Engagement.** Stakeholders may agree to utilize specific forms of communication (e.g., press releases, success stories, television interviews) and decide not to collectively engage in others (e.g., social media). In each case, these types of arrangements are useful in coordinating among stakeholders so there is no duplication of effort, or worse, conflicting versions of the same story.

- **Managed Public Engagement.** In early ICM deployments, it may not be clear who is the designated engagement lead for the corridor. However, as the ICM solution matures, a designated spokesperson who can articulate the vision, goals, actions, and successes of the corridor project can be invaluable. This ensures a consistent message and may be critical in maintaining momentum for corridor management projects.
- **External Stakeholder Registry.** Maintaining a registry of external stakeholders can prove valuable when trying to reach groups regarding upcoming corridor activity. Examples include school bus fleet managers, ride-hailing providers, city/county event planners, and work zone managers.

Example(s)/Insights:

- **List of Contacts.** Even in early ICM deployments, it may be valuable to document peer-to-peer relationships among ICM stakeholders and the influencers such as local media outlets. Later, it may be useful to document the organizational structures of media contacts and maintain a contact registry.
- **Special Considerations for Ped/Bike Stakeholders.** Reaching this community effectively means more than just reaching the public. Key influencers/advocates from the community can be instrumental in creating a controlled engagement activity so that these key stakeholders can contribute to the message and the media used to convey this message to this community.

Technical Arrangements

Technical arrangements (see FIGURE H.3) govern the ownership and responsibility among stakeholders for the security, monitoring, maintenance, and enhancements of ICM system assets (both tangible and intangible).

In addition to considering the nature of the arrangements themselves, any other related arrangements dealing with inputs/outputs of the system itself should also be considered. Every ICM system both ingests and produces data. In some cases, non-disclosure agreements may be required if the system ingests freight information. Similarly, specific elements of a stakeholder organization may need to be consulted to ensure that individuals on a transit agency network can introduce connections to external networks for data sharing with corridor users (outputs).

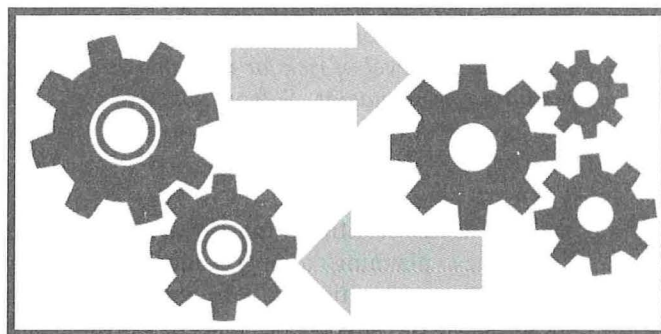


FIGURE H.3. Technical arrangements.

Data Management Arrangements

These arrangements document the agreements among stakeholders regarding data sharing, privacy, and data ownership. Without such plans the ability to build trust among stakeholders to engage beyond simple coordination in the corridor may be limited, as complex ICM strategies often require the ingest and dissemination of significant data resources. Data management arrangements reference or are drawn from an ICM-focused Data Management Plan (DMP). These plans summarize the data that are expected to be

produced during the project, describe the standards to be used for data (including metadata), deal with the access to and long-term storage of data, and identify the policies/licenses for access, use, and redistribution. It is critical for all ICM stakeholders to have consistent policies about data sharing, release, and redistribution—otherwise, there can be significant degradation of trust among stakeholders after “unimportant” data from one stakeholder is shared by another without permission. Conversely, if no clear policies are established, stakeholders may become unnecessarily reluctant to share data—this can work directly against goals to deepen integration among corridor stakeholders.

- **Data Sharing Among Stakeholders.** Often ICM stakeholders will focus on real-time data access and sharing. A possible sticking point to these discussions is finding standard data formats (where standards may not readily exist) to facilitate the sharing of the data. While real-time access and sharing are critical for joint agreement and documentation, comprehensive planning should include identifying which stakeholders may be responsible for maintaining data records over time. Note that both for management costs and privacy concerns it may *not* be advantageous to preserve all data in its most disaggregate form forever.
- **Open Data.** As opposed to data sharing among stakeholders, it may be advantageous to consider Open (public) data sharing. These arrangements can lead to innovative reuse of corridor data that can further support and promote the ICM concept. However, open data sharing must be balanced with privacy considerations (see resources below).
- **Data Ownership.** Data shared, documented and provided by the ICM system may not have a clear owner since they are likely data composites drawn from multiple stakeholders. One suggested path is to make the ICM organization the owner of these data products and establish clear rules for third-party distribution/use of these data. In some cases, the ICM system and the staff that deal with these data may handle proprietary data.
 - **Special Considerations for Freight Stakeholders.** There are often concerns about sharing real-time freight movement data. These concerns can be managed using NDAs and clear rules related to data cleansing and aggregation. A useful example to consider for ICM is the American Transportation Research Institute (ATRI) freight performance measurement project, where ATRI acts as a trusted third party to aggregate truck position and speed to characterize nationwide freight mobility performance. <http://atri-online.org/2012/02/28/freight-performance-measures/>.
- **Privacy and Liability Considerations.** When data are combined into new forms, there may be privacy and liability concerns to consider. For example, detailed vehicle position data (or video) may be combined with crash data raising concerns regarding liability. Likewise, detailed information on vehicle location may have privacy implications when combined (externally) with other available data. As an example, the NYCDOT CV Data Pilot program has developed a detailed plan to balance the need to protect privacy and mitigate liability risks while still supporting performance measurement needs with an innovative data aggregation and storage process. <https://rosap.nhtl.bts.gov/view/dot/31727>.

Example(s)/Insights:

- Iowa State Guide to creating a Data Management Plan <http://instr.iastate.libguides.com/dmp/dot>.
- USDOT Data Sharing Guidance for Connected Vehicles: <https://rosap.nhtl.bts.gov/view/dot/31609>.
- Freight Data Sharing Guidebook NCHRP 25 <https://www.nap.edu/read/22569/chapter/1>.

- Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management <https://www.nap.edu/download/13730>.
- USDOT Open Data Policy <https://project-open-data.cio.gov/policy-memo/>.
- FTA Open Data Policy Guidelines <https://www.transit.dot.gov/research-innovation/fta-open-data-policy-guidelines-report-no-0095>.
- Integrated Corridor Management, Transit, and Mobility on Demand Report <https://ops.fhwa.dot.gov/publications/fhwahop16036/index.htm>.
- Cook DuPage report: <https://www.tripspark.com/customer-success/in-vehicle-technology-story-cook-dupage>.
- Ped/Bike Data Clearinghouse <https://sites.google.com/site/bikepeddata/bp-t3-data-clearinghouse>, example data from Portland: <http://demo.portal.its.pdx.edu/pedbike>.

Cyber Security Arrangements

These arrangements document the agreements among stakeholders regarding protecting the cybersecurity of the ICM system including the potential impacts of security breaches regarding confidentiality, integrity, and availability along with the potential threats. Without such arrangements, the ability to collectively plan on joint security and respond quickly and effectively to cybersecurity threats may be limited.

- **Attack Surfaces.** The implementation of a shared ICM system may provide significant benefits but it also expands the number and type of places that hackers can launch an exploit. This increased set of potential vulnerabilities is known as the attack surface of the ICM system. Often, there is a misconception that organizational private networks are necessarily secure networks. Once there is connectivity among systems, there is also a potential to launch an attack from the least secure subsystem in the connected system.
- **Risk Management.** These arrangements should address joint risk management planning, as it is not possible that a completely secure system can be maintained indefinitely. This may also include joint cybersecurity hygiene practices that each stakeholder agrees to uphold, e.g., maintaining updated security patches across all component subsystems. Where cybersecurity risks are rated high, consider periodic black hat/white hat exercises to identify weaknesses in system security.

Example(s)/Insights:

- CV Pilot Security Management and Operations Concept development -- guidance document <https://rosap.ntl.bts.gov/view/dot/3599>.

Systems Engineering Management Arrangements

These arrangements document the agreements among stakeholders regarding how systems engineering for the ICM solution will be conducted and how systems engineering documentation will be managed over time. Without such arrangements, the ability to coordinate among stakeholders to implement more complex ICM strategies may be limited. Arrangements of this type can be often referenced or be directly derived from a solid Systems Engineering Management Plan (SEMP).

- **Maintaining Documentation.** Decentralized systems engineering can be a recipe for disaster in ICM planning—and similarly, lack of a plan to maintain and enhance Concepts of Operations, Architecture, Design, and Testing documents can be both frustrating and expensive for dynamic ICM deployments. Key agreements should be made regarding the joint process for developing and maintaining these documents, and/or preserving documentation from agile development methods utilized.
- **System Acceptance and Operational Readiness Testing.** When are new capabilities deemed ready enough to be incorporated into ongoing corridor operations? Since a corridor is a shared entity, there should also be shared agreement on what constitutes sufficient acceptance and readiness testing. These kinds of considerations tend to be overlooked in the rush to initially deploy a new ICM—however, long-term arrangements are needed that define the cases in which joint testing or at least shared understanding when new capabilities are rolled out that may have an impact on the ICM system.

Example(s)/Insights:

- Smart Columbus SEMP document <https://trid.trb.org/view/1477653> .

Collaboration Considerations

‘There are known knowns. There are things we know that we know. There are known unknowns. That is to say, there are things that we now know we don't know. But there are also unknown unknowns. There are things we do not know we don't know.’ – Donald Rumsfeld, U.S. Secretary of Defense, 2002.

The arrangements discussed so far deal with the known issues and scenarios facing ICM stakeholders, as in the “known” and “known unknown” issues articulated in the quote above. However, no set of arrangements can be ironclad against all eventual scenarios. In some cases, the ICM stakeholders must also have general collaboration considerations in place to deal with the “unknown unknowns”, that is, the things that could not be planned for but require a collective response.

This section notes the following additional collaboration considerations to note when planning and deploying ICM. Some examples:

- Resolution of general disagreements or setting a course of action in situations that have not been specifically addressed in advance (incorporate into institutional arrangements, particularly governance policy arrangements).
- Mechanism for changing course of action when partner agencies encounter problems and are unable to proceed or continue (incorporate into institutional arrangements, particularly governance policy arrangements).
- Provisions for requiring ongoing commitment and participation to ICM for successful operation (i.e., protections for the common investment), as well as provisions for leaving the ICM commitment if it becomes infeasible for the stakeholder to continue participating (i.e., protections for the individual stakeholders).
- Internal and public response to worst-case corridor scenarios (disaster, loss of life, malfunction, cyber security). Specific plans need not be laid out. However, it may be useful to consider laying

out a general “bad news” strategy, potentially as a part of organizational arrangements dealing with safety management and external stakeholder engagement.

For more discussion of institutional, organizational, and technical arrangements useful to ICM deployers, additional resources include:

- NCHRP 337 http://teachamerica.com/accessmanagement.info/pdf/nchrp_syn_337.pdf.
- ICM Knowledgebase https://www.its.dot.gov/research_archives/icms/knowledgebase.htm.
- P3 homepage <https://www.fhwa.dot.gov/ipd/p3/>.

Key Arrangements for Integrated Corridor Management Deployments by Maturity Level

This section provides a structured exercise for ICM stakeholders to assess the maturity of the existing ICM institutional capital and to identify the most likely technical, organizational, and institutional arrangements to either create or enhance. This exercise can be useful for ICM deployments in a range of deployment maturity—from early to advanced deployments. Such an exercise is recommended when the ICM solution needs to be expanded to include new stakeholders (e.g., freight, transit, incident management, and ped/bike stakeholders).

Exercise Purpose. The purpose of the exercise is to collectively assess the maturity of current ICM institutional capital with respect to current or future needs and identify and prioritize the creation or updating of specific institutional, organizational and technical arrangements.

Exercise Outcomes. The expected outcomes of the exercise are to:

- a) Improve the level of engagement of all stakeholders in a shared ICM vision, and
- b) Create a punch list of high-priority actions to be taken in strengthening arrangements among stakeholders.

When to Conduct This Exercise. This exercise (or something similar in intent) can be incorporated into a periodic (e.g., annual) meeting of ICM stakeholders. In many cases, it may be useful as a capstone exercise after a broader discussion of corridor performance, needs, and stakeholders. If this discussion has not been facilitated, then additional time must be added to the exercise to provide the context of corridor vision and key next steps that will shape what is needed in terms of institutional capital.

Who Should Participate. The exercise is intended for the individuals who are the champions of the corridor concept. These need not necessarily be drawn from the ranks of senior leadership among stakeholder organizations. At least one participant should attend for each of the major corridor stakeholder groups. That said, the exercise would be impractical for large groups. A practical maximum of 16-20 participants with a target size of 6-12 motivated stakeholders can be used as a rough guide to help size the exercise and determine who should participate.

Required Preparation and Materials. The exercise is designed to be conducted as an in-person, roundtable event. However, a virtual participation by some (or even all) stakeholders can be supported given that there is a method to collect and display information that all stakeholders can simultaneously view. A no-visual teleconference connection is not recommended for any participants. Practically, this means at a minimum a whiteboard for a purely in-person event. However, an arrangement where a computer desktop can be simultaneously viewed (by both in-person attendees and virtual attendees) is likely to be the

best solution. One individual should be assigned the role of exercise facilitator (and timekeeper) and another assigned the role of recorder/scribe for the exercise.

Plan for at least a 90-minute block to conduct the exercise, split 30 – 60 between the two major steps. Specifically, plan for at least 30 minutes for the collective maturity assessment and at least 60 minutes for the deep dive on identifying specific arrangements to create or update.

Prior to the event, exercise organizers should compile all current arrangements and be ready to share both a high-level list of these arrangements (needed in Step 1) and be able to display individual arrangements (needed in Step 2). Further, the list of arrangement types from earlier in this appendix can be a useful reference for participants.

Step 1: Collective Maturity Assessment of Current Integrated Corridor Management Institutional Capital

The first step in the exercise is to consider the maturity of the ICM system stakeholder institutional capital. Utilize the list of current arrangements (provided as a handout to all participants) and the NCHRP ICM capability maturity model (see FIGURE H.4) in this exercise to characterize the level of maturity indicated by the current collection of arrangements. This characterization should be conducted with respect to five different elements and to generate five different ratings:

1. Without respect to freight, transit, incident management, and pedestrian/bike stakeholders.
2. With respect specifically to freight stakeholders.
3. With respect specifically to transit stakeholders.
4. With respect specifically to incident management stakeholders.
5. With respect specifically to pedestrian/bike stakeholders.

		Level 1 Solo	Level 2 Centralized	Level 3 Partially Integrated	Level 4 Multi-modal Integrated	Level 5 Multi-modal Optimized
Institutional Integration	Inter-agency Cooperation	Agencies do not coordinate their operations	Some agencies share data but operate their networks independently	Agencies share data, and some cooperative responses are done	Agencies share data, and implement multi-modal incident response plans	Operations are centralized for the corridor, with personnel operating the corridor cooperatively
	Funding	Single Agency	MPO tracks funding	Coordinated funding through MPO	Cooperatively fund deployment projects	Cooperatively fund deployment and operations and maintenance projects
Technical Integration	Traveler Information	Static information on corridor travel modes	Static trip planning with limited real-time alerts	Multi-modal trip planning and account-based alerts	Location-based, on-journey multi-modal information	Location-based, multi-modal proactive routing
	Data Fusion	Limited or Manual	Near real-time data for multiple modes	Integrated multi-modal data (one-way)	Integrated multi-modal data (two-way)	Multi-source multi-modal data integrated and fused for operations
Operational Integration	Performance Measures	Some ad hoc performance measure based on historical data	Periodic performance measures based on historical data	High-level performance measures using real-time data	Detailed performance measures in real time for one or more modes	Multi-modal performance measures in real time
	Decision Support System	Manual coordination of response	Pre-agreed incident response plans	Tool selection of pre-agreed plans	Model-based selection of pre-agreed plans	Model-based creation of incident response plans

FIGURE H.4. NCHRP Integrated Corridor Management Capability Maturity Model (for use in exercise).

Using the NCHRP ICM Model in Step 1. The model, while useful, is not a perfect match for assessing institutional capital. First, a structured discussion on how current arrangements line up with the horizontal elements can set the stage. Institutional Integration maps well into Institutional Arrangements, Technical Integration into Technical Arrangements, and Operational Integration into Organizational Arrangements. Assess whether the agreements indicate maturity level from 1.0 to 5.0. Based on the current arrangements, where would an independent observer who was able only to read these documents rate the maturity of what had been documented? For the exercise, having one participant lead this discussion followed by a showing of hands around level of maturity assessed by each participant can be useful. Outlier assessments should be discussed by the group to arrive at a consensus value (or average value, if consensus cannot be reached), rated between 1.0 (least mature) and 5.0 (fully mature).

Trust Relationships are Not Durable Institutional Capital. Sometimes there is a stronger “feeling of ICM coordination” than reflected in documented ICM arrangements. In this exercise, however, our collective focus is on *documented arrangements*. Strong trust relationships among individuals or organizations can make it feel like documenting informal arrangements is just extra work. However, much like a committed couple may feel that legal paperwork formalizing the couple’s arrangements is too much hassle or too expensive—when the underlying situation changes, trust relationships may also change. In most of these cases, however, good legal advice will often point out that if the relationship is intended to be long-term, then formalized arrangements are needed to document, preserve, and protect the long-term shared (and individual) interests of the couple over time. Less metaphorically and more specifically, this implies that trust relationships cannot be counted on to be durable over the long term for ICM solutions. In this case, the strength of the durable ICM stakeholder collective vision is only as strong and durable as the institutional arrangements that document this collective vision. Likewise, the amount of deployed equipment (e.g., sensors and controls) is not always proportional to the maturity of ICM institutional capital. Vast and complex subsystems without arrangements for their (at a minimum) coordination and (eventual) appropriate level of integration may have a very low maturity assessment level for its institutional capital.

Weakest Link Analysis. Note that there may be a separate higher rating for a current ICM solution without a history of integrating stakeholders from the freight, transit, incident management, and pedestrian/bike stakeholder communities. However, we are interested in the *lowest* of the ratings to describe ICM maturity for this exercise. Why? There may be a need to return to basics to incorporate the vision and needs of new stakeholders. A common mistake is to assume that new stakeholders can be routinely absorbed into existing organizational forms. The risk in this case is that the new stakeholders and charter stakeholders are never on the same page conceptually, technically, and organizationally. Negative impacts of *ad hoc* incorporation of new stakeholders can be expensive and institutionally damaging to the ICM concept—since it has an impact on shared trust, perhaps the most crucial shared resource for ICM stakeholders. Where stakeholders are considered critical but not represented in the exercise, consider conducting the exercise again in the future when these stakeholders can be invited and can participate.

Classify Overall Maturity. Using the lowest of the five ratings as a guide, as a group, consider three general classifications for overall maturity using our exercise:

- *Emerging ICM Deployments:* Maturity ratings of 1 in most categories, particularly for operational and institutional integration. These deployments may be considered *aspirational* ICM deployments in that there is a significant motivating need for a more integrated solution to corridor management, but little institutional capital.
- *Intermediate Deployments:* Maturity ratings of at least 2-3 in most categories, particularly for institutional and operational integration. These deployments are generally representative of corridors after some initial effort at creating a comprehensive ICM solution. As the ICM system

matures, there is a need to maintain deployment momentum and create a culture of continuous improvement or risk falling back into old siloed ways with the initial project now complete.

- *Advanced Deployments:* Maturity ratings of at least 4-5 in all categories. These deployments are generally representative of long-standing ICM capabilities now considering more formalized financial and institutional models.

Step 2: Identify Critical Integrated Corridor Management Institutional Capital Needs (Create or Update)

In this step, we utilize an adapted form of the ICM Implementation Guidance (see FIGURE H.5) to help characterize the gamut of issues facing the ICM deployment, and to gain insight on the highest-priority arrangements to be either created or updated. This provides structure to this step in the exercise to ensure that all issues and needs are considered, not just the most immediate and pressing concerns. Further, different institutional arrangements may be required or updated based on the type of consideration.

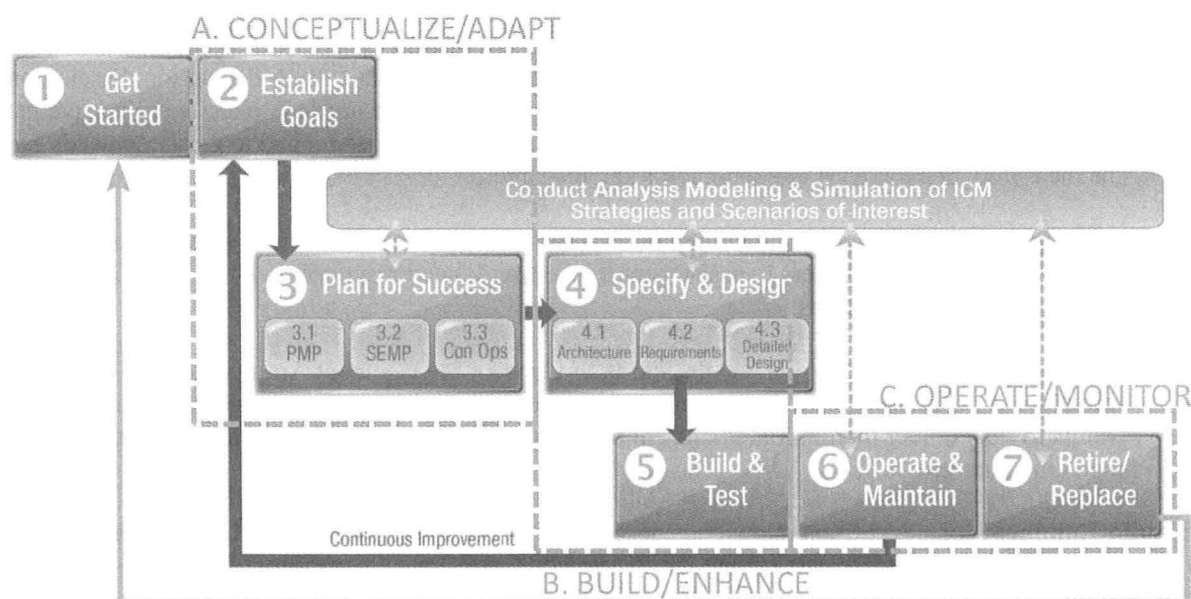


FIGURE H.5. Adapted Integrated Corridor Management implementation process (for use in exercise).

Using the Adapted ICM Implementation Process. Rather than try to address everything all at once, the implementation guide provides a useful structure to help in our exercise. We can now examine three distinct phases within the ICM continuous improvement process when considering the need and urgency to create or update institutional, organizational, and technical arrangements:

- *A: Conceptualize/Adapt.* The current ICM concept, boundaries, scope, stakeholders or intent have changed. What success looks like and how it is measured may need to be reexamined. The focus here is primarily on institutional arrangements.
- *B: Build/Enhance.* Investments have been identified to improve corridor performance but the plan for how to build these new capabilities into the existing system must be determined. Stakeholders must be assured the new system is well designed, maintainable, and tested before bringing new capabilities into routine operational practice. The focus here will be primarily on aspects of technical arrangements.

- *C: Operate/Monitor.* Operational practices must be updated or altered because of changes in underlying corridor demand, new user needs, the introduction of new technologies, or a change in corridor strategy. The focus in this exercise relates primarily to organizational (operational) arrangements.

Exercise for Emerging (Early) Deployments

The identification and prioritization activity is broken into three parts. First, we consider the current set of arrangements and their suitability for future use from the vantage points of the Conceptualize/Adapt (A), Build/Enhance (B) and Operate/Maintain (C) perspectives.

A: Conceptualize/Adapt Considerations. Here, there is an aspiration either to create a new corridor community or to adapt an existing community significantly to incorporate a new set of stakeholders. The reason for this may be quite specific—sometimes because of a particularly problematic corridor experience, or the need to create a corridor concept to pursue external funding. In this exercise, however, participants are asked to think broadly regarding needs, not just a specific recent use case.

- Prioritize Top Corridor Needs. Stakeholders share the top five corridor issues/problems that need to be resolved. A scenario-based approach can be useful to frame this needs discussion. Discussion of common issues among corridor stakeholders. Seek to integrate needs into a comprehensive list of no more than 5 top needs. Consider whether corridor performance related to these top needs can be measured. See the ICM Guidebook for key resources.
- Identify Stakeholder Impact and Potential Response. For each need, determine impact and potential actions taken by stakeholders to assist as part of a coordinated response. See the ICM Guidebook for resources/considerations.
- Create/Update Corridor Vision, Goals, and ICM Concept Management Arrangements. Take the products of the previous two steps to create or update the corridor vision and goals. If there are limits to stakeholder integration, document this as a part of limitations for systems integration agreement language.

B: Build/Enhance Considerations. Now consider what kinds of capabilities an ICM system might need to address the top five needs/use cases. Here the focus is on the technical capability of the ICM system to sense and identify current conditions—and adapt corridor management strategies on the fly.

- Describe New or Enhanced Applications Needed. Are new capabilities needed to realize stakeholder response? If so, create a short list of the most critical, no more than 10 in total. Note that this is in response to the complete set of needs, not for each need.
- Identify Gaps and Required Technical Integration. Rate each of the new capabilities as a major, minor, or no gap compared to current deployed capabilities. In each rating, note which stakeholders would need to be involved in deploying the technical solution—and if there are arrangements for coordinating an integrated solution. Second, note where data would need to be shared among stakeholders—and if arrangements are in place for supporting these data flows.
- Create/Update Systems Engineering Management Arrangements, Data Sharing Arrangements. Take the products of the previous two steps to note needs to create or update engineering arrangements linked to a SEMP, and data sharing agreements.

C: Operate/Monitor Considerations. Now consider what kinds of operational coordination among stakeholders would be needed to realize the technical capabilities discussed in the prior step.

- Rate Operational Readiness. For each of the 10 critical technical capabilities, rate the readiness of stakeholders to realize this in operational form as either major, minor, or no operational gap. In each, make a note of the rationale/barrier to realizing this capability.
- Create/Update Operational Mode and Procedures Arrangements. Take the products of the previous two steps to note needs to create or update high-level operational arrangements.
- Wrap Up. Now briefly consider if there is a need to document or update other specialized elements to document in institutional, organizational, and technical arrangements. This may be as simple as noting a need to modify organizational form in the institutional arrangement, or a note regarding cybersecurity needs for technical arrangements. An output of this effort is the list of high-priority actions needed to be taken regarding arrangements among stakeholders. It may be useful while the group is assembled to further prioritize proposed actions (if needed) and assign a stakeholder lead to carry out the actions associated with creating new arrangements or updating current arrangements.

Exercise for Intermediate Deployments

Repeat the Early Deployment Exercise with the following modifications/additions to the three substeps.

- A. *Conceptualize/Adapt Considerations.* Additionally, address needs related to System Integration arrangements, and specifically identify Financial and Capital Planning Arrangements needed to fund the enhancements.
- B. *Build/Enhance Considerations.* Specifically call out needed updates to Operational Readiness/Acceptance Testing arrangements.
- C. *Operate/Monitor Considerations.* Note all needs to create or update a separate detailed set of Cyber Security Arrangements. Note changes to Tactical Operations Action Planning Arrangements.

Exercise for Advanced Deployments

Repeat the Early Deployment Exercise with the following modifications/additions to the three substeps:

- A. *Conceptualize/Adapt Considerations.* End with a step assessing the limitations of current Financial and Capital Planning arrangements and related Organizational Forms and Governance Policy arrangements. Note potential steps and possibilities of more advanced organizational forms (see next section).
- B. *Build/Enhance Considerations.* Include explicit consideration of Safety/Emergency Management Arrangement and Data Privacy Arrangements.
- C. *Operate/Monitor Considerations.* Assess need for update to External Stakeholder Engagement Protocols/Procedures Arrangements.

Alternative Integrated Corridor Management Frameworks

Searching for innovative, new ICM stakeholder engagement frameworks or strategies can benefit from evaluations of similar efforts that have been performed by other entities and organizations in analogous contexts in other industries. Potential sources of such frameworks may involve coordinating large projects among a diverse set of stakeholders with different interests.

Six example frameworks are presented here for the purposes of helping ICM stakeholders to assess potential initial ICM organizational forms—and as the ICM system matures and develops over time, alternative forms that may be better aligned with the needs of the ICM community. Frameworks are presented in the order of increasing ICM complexity and integration, starting with frameworks most often considered in the early stages of ICM deployment and concluding with potential advanced ICM frameworks where corridor management roles and practices are well defined and more formal corridor-specific organizational structures are required to improve efficiency and accountability. Many ICM systems will function best using early organizational forms—and may not need to move beyond less formal frameworks. However, under specific circumstances, more advanced and formal frameworks may be required to deliver on the strategic corridor vision—and the ability to react flexibly and efficiently to the challenge of corridor management.

Each of the six frameworks is documented here with a conceptual diagram, a text description, a discussion of strengths/weaknesses, and examples drawn from transportation and other industries.

Ad Hoc Coordination (Early Model)

In this early model (see FIGURE I.1), there is no formal charter or ICM concept. However, there is corridor-level coordination that occurs informally among stakeholders because of the natural intersection of corridor issues, events, conditions and aspects that may have brought stakeholders together in the past. In some cases, staff in one organization may have worked previously in another organization and there are personal relationships that act as natural bridges among corridor stakeholders. Often, the eventual success of developing an early ICM concept is dependent on these kinds of informal connections among individuals who have developed trust relationships that span multiple ICM stakeholder organizations. Among these

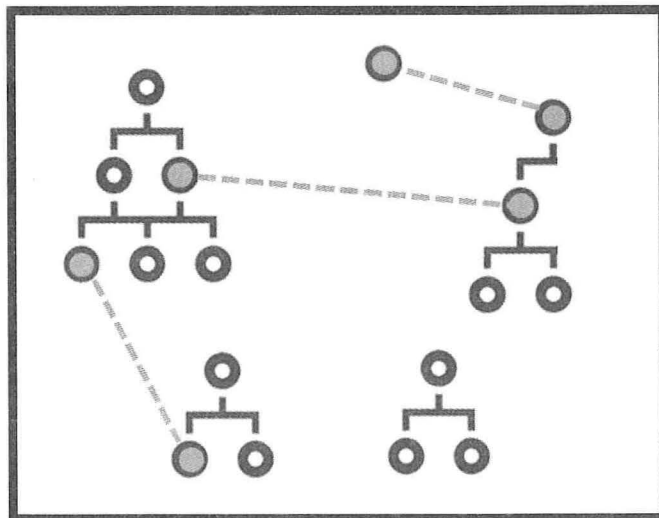


FIGURE I.1. Ad hoc coordination (early model).

individuals, there may be a documented corridor vision statement or short description that describes shared intent.

In the diagram shown above, the *Ad Hoc Coordination* model can be characterized as a collection of these trust relationships. The open circles represent individual staff, and the solid black lines between them reflect formal organizational chains of command in terms of supervisors, direct reports, and peers. Trust relationships among pairs of staff in different organizations relevant to ICM coordination are highlighted with orange dashed connections. Note that ICM stakeholder organizations may be relatively large (e.g., law enforcement or transit agencies) or as small as a single individual (e.g., a private citizen acting as an advocate for pedestrian safety, or an independent freight owner/operator). Note that the diagram shows that some organizations may have more of the ICM-relevant trust relationships, while others may have none. In this model, there may be some coordinated action to develop new relationships or bring new stakeholders together to discuss shared problems and issues. However, there is no formal organizational structure beyond a registry of ICM stakeholders and the organizational capability to conduct periodic meetings of these stakeholders.

Strengths:

- **Low cost.** This framework can be an effective and useful framework to create momentum for an early ICM concept.
- **Strong trust among participating stakeholders** since the individuals know each other and relationships are primarily personal.
- **Trust relationships can be maintained and strengthened** using relatively informal means—meet-ups, invitations to corridor stakeholder events, shared fantasy sports leagues. These events can also be used to network the trust relationships beyond single individual to single individual relationships.

Weaknesses:

- **Lack of defined organization** may result in the ICM concept to be skewed towards the existing trust relationships, and may leave out key stakeholders where relationships do not exist—or focus on sub-problems that do not address more fundamental underlying corridor-level issues.
- **Difficult to scale.** Trust relationships are individual-to-individual and not always transferable. Just because Erica has a trust relationship with Kenny, and Kenny has a trust relationship with Amanda—it is not always a sure thing that Erica and Amanda will also have (or easily develop) an equivalent trust relationship. Further, this framework is subject to replacement risk if key individuals take a new job, move to a new area, or retire.
- **Ad hoc impact.** The ad hoc nature of relationships implies that impact is similarly ad hoc—which in some areas may be effective, but in other key areas may have no capability to address corridor issues because of a lack of existing trust relationships.

Best Applied:

- **Early ICM Deployments with Limited Institutional Momentum.** The Ad Hoc model can be an effective model to follow when the ICM concept is in an early state and institutional momentum needs to be generated to move towards a more comprehensive solution. The framework is not included here as an organizational counter-example—in some cases, the needs of a corridor can be

fleshed out when a collection of existing trust relationships can be identified and cataloged. These existing trust relationships and the informal value of coordination among agencies can jump start an ICM concept-building activity because it shows that there is a real need and there are already individuals in place working to resolve corridor-level issues.

- **When A Representative ICM Victory is Within Grasp.** In some cases, a specific corridor issue or situation can be addressed with limited coordination among a handful of individuals with strong trust relationships. In these cases, there is an opportunity for informal corridor-level coordination to create a success story that can motivate others to join in a broader ICM concept development and implementation effort. Metaphorically speaking, people are more likely to want to jump onto a moving bandwagon with demonstrated forward momentum rather than a motionless bandwagon with the potential to move forward.

Examples/Insights:

- **Follow the Data.** In some cases, there may be trust relationships among individuals related to sharing corridor-related data. These connections can potentially launch a low-cost, high-impact effort to mash up or integrate available data to help improve the dissemination of the information among corridor travelers who may be considering alternative modes (e.g., transit riders and bike commuters). This early win can create momentum to find more ICM-relevant scenarios. Examples of organizations that may serve as a springboard to ICM include groups that share and visualize data like the OpenStreetMap initiative. This initiative exists to create and provide free geographic data, such as street maps, to anyone. The OpenStreetMap Foundation is an international not-for-profit organization supporting, but not controlling, the OpenStreetMap Project. It is dedicated to encouraging the growth, development and distribution of free geospatial data and to providing geospatial data for anyone to use and share. In this case, the OpenStreetMap project is not an ICM example, per se, but rather an example of existing connections among stakeholders that create new capabilities together, e.g., a map of usable bike paths and pedestrian paths, as well as transit services.

- For more on OpenStreetMap, see: https://wiki.osmfoundation.org/wiki/Main_Page)

Roundtable of Champions (Early Model)

In this early model (see FIGURE I.2), senior leaders gather together to initiate or further develop an ICM concept. In this case, creating a charter for the corridor stakeholders and establishing goals may be an early agenda item.

In the diagram on the side, the *Roundtable of Champions* model can be characterized as relatively senior management in each organization creating a roundtable of similar individuals across the ICM stakeholder spectrum and inviting participation. Note that, as depicted, the roundtable is reserved only for senior managers, from the top of each of the subsidiary org charts. These senior managers take time away from their typical duties and participate in roundtable events to discuss corridor-level issues, performance, and potential forms of coordination. Note that these individuals do not leave their regular day jobs behind them—but add representing their organization at the roundtable to their roles and responsibilities list. For stakeholders with well-defined organizational charts, who serves in the Roundtable of Champions may be simple. For other key stakeholders, it may not be clear who can/should act as an advocate (e.g., pedestrian or bike stakeholders), or there may not be an obvious neutral third-party advocate to represent competing stakeholders (e.g., corridor freight carriers).

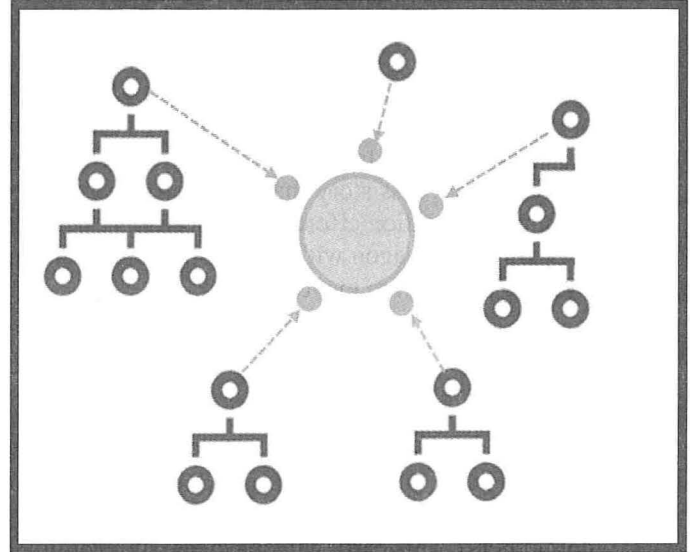


FIGURE I.2. Roundtable of champions (early model).

Strengths:

- **High visibility.** When a senior leader shows an interest in corridor-level performance and issues, other parts of the organization and the public will take notice. This, in turn, may encourage senior leadership from other stakeholder organizations to participate, even if they had not been engaged earlier.
- **Senior Leaders Can Set Vision/Direct Action.** Buy-in from the top is critical to consider implementation of many of the most effective ICM strategies.
- **Durable Organizational Relationships.** Roundtable participation/invitation is based on title, not the individual. If there is turnover within organizations, the successor to the senior management position inherits the roundtable seat for their organization.

Weaknesses:

- **Risk of “Shallow” Coordination.** In some cases, there may be interest in showing coordination but the group may lack inherent momentum to tackle specific issues at a technical level. High-level descriptions of shared vision may lack a focus on specific actions or pilot projects to be conducted. Further, senior managers may have extremely limited time to dedicate to corridor issues when there may be many pressing organizational, financial, and technical issues within their own home

organizations. This can lead to good intentions but a lack of focus at senior level outside of the roundtable events themselves.

- **Difficult to Manage Rapid Growth.** Some roundtables become large quickly—and in these cases, it may be impractical to organize and schedule. Keeping the roundtable small to start and then incrementally expanding membership can be a smart counter to this threat, but the risk is in alienating other stakeholders who would like to join but are initially put off.
- **Stakeholders with No Clear Organizational Chart.** In many cases, it may be hard to find a single voice that can speak for a broader stakeholder community (see above regarding bike/ped and freight stakeholders). The same issue arises among stakeholders who have distributed jurisdictional control within the corridor (e.g., multiple transit agencies). In other cases, it may not be clear who within an organization has the power to influence and direct even a highly structured corridor-specific project. In other cases, the actual power to put ICM strategies in place may be confounded by fiefdoms within a large organization. Some individuals will likely see ICM as a threat to their subsystems or subsystem performance and not be inclined to support ICM activity.

Best Applied:

- **Early ICM Deployments with Risk Averse Stakeholders.** Some organizations are highly risk-averse. Organizational top cover may be needed to institute a change in long-standing processes and procedures—and get buy-in to create new ICM-focused measures and processes.
- **Responding to Grant/Funding Opportunities.** An important catalyst for ICM in gaining the attention of senior management is the urge to coordinate in the goal of winning a grant or other competitive funding source related to ICM implementation. Here the shared goal among the stakeholders is clear—to develop a compelling, comprehensive, and technically feasible ICM concept as a shared team.
- **Capitalize on Success.** Alternatively, a good success story like the one described in the *Ad Hoc Coordination* framework discussion can lead to the creation of a viable and energized *Roundtable of Champions* as a next logical step.

Examples/Insights:

- **USDOT ICM Pioneer Proposers.** In 2007, the initial set of ICM Pioneer sites responded to an initial grant opportunity around the original ICM initiative. In this case, the typical point of departure for proposing locations was to capitalize on early ICM connections made at a high level to set the tone and prepare a detailed proposal. Of the early models detailed in this appendix, this is the best framework to consider if the ICM stakeholders intend to pursue external funding to advance the ICM concept and/or deploy pilot capabilities.
- **Lead Agencies.** A discussion of the role of champions in the San Diego and Dallas sites is included in the upcoming ICM Evaluation Report (Battelle, 2018). An interesting insight provided here is that one or more champions from agencies with corridor-wide responsibility often emerge in lead roles when a roundtable of champions is initially formed.

Peer-to-Peer Connection (Early Model)

In this early model (see FIGURE I.3), technical and operations staff gather together to solve specific corridor issues. In this case, this is a natural extension of the *Ad Hoc Coordination* model but advanced to a more mature state where trust relationships among multiple individuals have evolved into trust relationships among sub-elements of individual stakeholder organizations.

These connections are encouraged, and possibly authorized, by the chain of command within each participating organization. However, the nature of these engagements is limited by the specific problem they are solving at a tactical level, and not endorsed or specifically chartered as a part of a more comprehensive ICM organizational form (e.g., as might be initiated in the *Roundtable of Champions* framework).

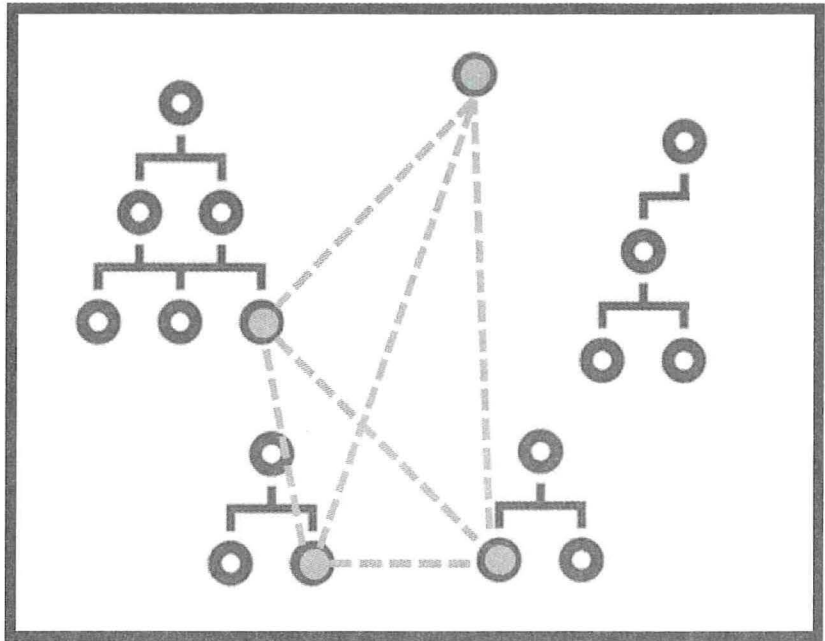


FIGURE I.3. Peer-to-peer connection (early model).

In the diagram shown above, the *Peer-to-Peer* model can be characterized as a collection of multiple, networked relationships among staff positions in multiple organizations. These trust relationships, indicated in broken orange lines, represent connections that may have originally been based on trust relationships among individuals but have matured over time to represent organizational connections. Existing communities of coordination around recurrent special events, e.g., annual state fair, major conventions, seasonal severe weather or emergency response, can assist early corridor planning and coordination among corridor stakeholders. An example might be connections among transit, freight, and bike/pedestrian stakeholders around managing goods and people movement in and around a large fairground for a 10-day period every year. In this case, there may be useful policies regarding when large freight deliveries might take place, when specific roads may be closed to all but transit or non-motorized traffic, or specific plans drawn up to deal with incidents or other emergencies that might arise during the critical 10-day period. While focused on specific event planning rather than more comprehensive corridor management, these relationships, policies, and coordinated activities can be critical building blocks for ICM. Some key corridor stakeholders may not be initially engaged (as depicted in the diagram where one organization has no orange connection lines) as there may not have been a good match between special event stakeholders and corridor stakeholders in early rounds of trust-building and organization formation.

Strengths:

- **Problem-focused.** Much like the scenario planning work suggested throughout this document as a good conversation starter for ICM solutions, the peer-to-peer network focused on recurrent event planning can be a useful springboard for a more comprehensive solution.

- **Practical.** These types of cases often have motivating examples of why coordination works and how everyone benefits.
- **Durable Organizational Relationships.** Trust relationships have matured into tactical forms of institutional trust among coordinating organizations—and less likely to be undone by staff moving on to new positions.

Weaknesses:

- **Low Visibility Until Something Goes Wrong.** Aside from high-visibility events like a major sports championship, even snow events and annual state fair planning may receive significant high-level organizational or public attention. Unless something goes wrong—and then there may be significant attention. If this is the case, then an organized recovery and lessons learned from such an outcome can also be the seed for a more comprehensive ICM solution.
- **May Not Be Well-Positioned to Seek External Corridor-Related Funding.** Such arrangements are tactical in nature and tend not to be flexible or scoped widely enough to be able to seek external funding. In addition, since these communities are developed around one or more events, rather than from the mental frame of a corridor, there may not be a good match to corridor-concept funding mechanisms.
- **Issue of Scalability.** Only a few days a year may warrant or may have warranted tactical coordination of this nature. The individuals and organizations managing the state fair operations may have limited overlap with the set of stakeholders from those that manage snow removal. It may be difficult to collect these groups, find common ground, and then scale up to a more comprehensive ICM solution without a more formal organizational form (e.g., at a minimum incorporating senior management buy-in in some form as in the *Roundtable of Champions* model).

Best Applied:

- **Busy Corridors with Recurrent Special Events.** Corridors that see little or no day-to-day congestion may have little need for a more comprehensive ICM solution—and instead the corridor management effort can be organized around the special events that drive unusual heavy demand patterns. These types of events are likely to affect a wide range of stakeholders, including incident management, transit, pedestrian/bike, and freight stakeholders.
- **Need for Comprehensive Integration is Low.** In these cases, the relatively infrequent nature of the events may not support the need for deep technical or organizational integration. Law enforcement may be engaged in managing critical intersections and protecting pedestrian movements during peak periods. The need for a more complex technological traffic control system may be low since the benefit of the system can only be recouped a few days in the year.

Examples/Insights:

- **Special Events as ICM Motivators.** Often, successful events like state fairs grow in popularity over time and can overwhelm the capability of planners to deal with them outside of a more comprehensive corridor-level strategy. A web-based survey of state fair activity in 2017 indicates nearly a dozen examples where traffic access was considered problematic (diverse locations that include the states of Wisconsin, New Mexico, Washington, New York, Iowa, Kentucky, and California), including transit and pedestrian access. An example for the 2017 New York state fair can be found at <http://spectrumlocalnews.com/nys/central-ny/news/2017/08/27/interstate-690->

state-fair-traffic. At least two of the USDOT ICM Pioneer sites incorporated state fair planning within their corridor concept development efforts (U.S.-75 Dallas and Twin Cities).

Coordinated Operations (Intermediate Model)

In this intermediate model (see FIGURE I.4), stakeholders have formalized an agreement to coordinate activity, either in a playbook or a set of flexible rules. This is the first intermediate model and represents a level of coordinated action and formalized organizational form at a tier above the three early deployment frameworks discussed so far. In many cases, the key difference between the early models and this intermediate model is a more mature set of institutional capital. Specifically, advancing to the intermediate framework requires more detailed operational and technical arrangements that spell out the specific roles, responsibilities and sequence of actions taken in response to observed conditions in the corridor. Rather than working from a general set of principles driving coordination among stakeholders at a broad level, this intermediate model seeks a set of (more or less) comprehensive response plans that stakeholders formulate together.

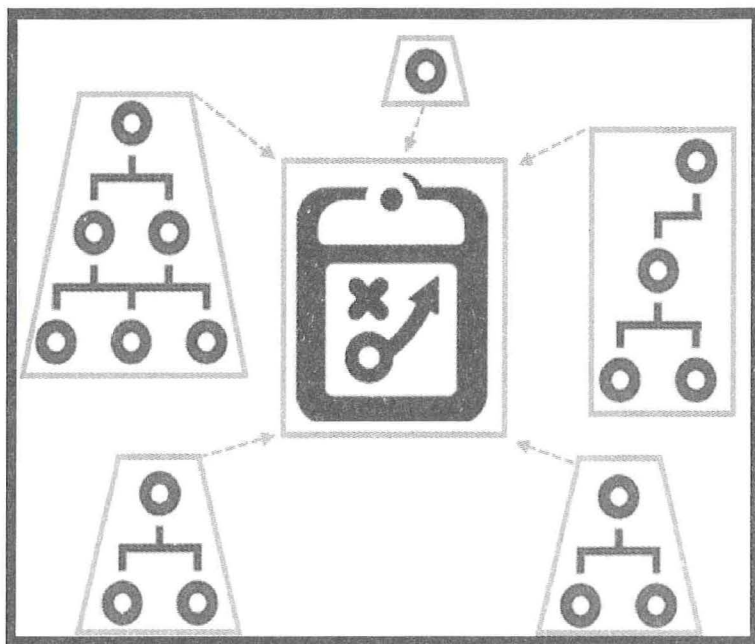


FIGURE I.4. Coordinated operations (intermediate model).

In the diagram shown above, the *Coordinated Operations* model can be characterized as a collection of stakeholder organizations (shown at the exterior points of the diagram) working together to create a detailed playbook (represented as the element in the center of the diagram) that deepens the level of coordinated action and technical integration among ICM stakeholders. Note that the dotted lines of trust relationships that dominate the diagrams for the early models are no longer the focus. Trust relationships among individuals and organizations are a given in this intermediate framework—and the focus has turned to leverage this trust relationship into developing arrangements describing in detail a set of more complex, coordinated actions.

Strengths:

- **Supports More Complex (and Effective) Deployments.** Some ICM strategies require high levels of detailed coordinated action. For example, a corridor may include some subelements where freight signal priority is required to assist on-time delivery at key intermodal facilities. Access to these facilities may run counter to optimal transit signal priority timing, bike lane access, pedestrian movements, and other considerations. In order to implement coordination among these competing corridor demands, detailed intersection and facility plans may be needed—far beyond informal coordination among the jurisdictions controlling the signals and the collection of stakeholders.

- **Higher Level of Responsiveness.** The development of a corridor playbook allows actions to be taken more quickly in response to a wide range of operational conditions.
- **Durable Action Plans.** One weakness of the early models is the general lack of detailed operational and technical arrangements, and a reliance on trust relationships to execute corridor actions. Such informal arrangements may be consistent with complex actions. However, when individuals change positions or retire, these undocumented plans are lost. Documenting the agreed-to actions allows new staff to step into clear roles with clear responsibilities and associated actions in the playbook.

Weaknesses:

- **Limits of the Playbook.** In complex corridors, the number of plays needed in a playbook may grow large quickly. Maintaining the playbook and updating it to changing conditions may be difficult and time-consuming. A detailed plan may be created for a situation that occurs infrequently (or never again). At the same time, operational conditions that warrant coordinated action but are not in the playbook may be large. At some point, a detailed playbook may need to be replaced with a more flexible set of rules that describe general actions to be taken supported by a set of automated adaptations. Whether such a system is needed depends on the repeatability and classification of the operational conditions experienced in the corridor—and the nature of the corridor management response.
- **Often Requires Corridor-Specific (External?) Funding.** Making the leap from one of the early models to the intermediate model often requires corridor-specific funding to both create the playbook and the supporting technical capability to implement it. Further, this model is difficult to leap into as a first step for an ICM stakeholders, since it is dependent on existing trust relationships already being in place among stakeholders (individuals and organizations).
- **Requires Institutional Maintenance.** The ICM playbook should not be viewed as a “one-and-done” activity. The playbook will need significant maintenance and enhancement over time. There should be an institutional commitment to periodically examine corridor performance, develop new plays (including modeling studies), and then to update the playbook. These updates may also require new technical arrangements and possibly new field capabilities.

Best Applied:

- **Target Next Step of Early ICM Frameworks.** Early framework ICM solutions that have an external or corridor-specific funding source are often good candidates for this level of integration. That is, the result of the funding is to advance to and realize an ICM capability Coordinated Operations, with the appropriate level of institutional capital.
- **ICM Showcases.** These types of deployments using this organizational form can serve as motivating examples of what is possible for deeper levels of corridor coordination.

Examples/Insights:

- **Current State of the Art.** Broadly, this intermediate state reflects the operational capability and organizational form of the USDOT ICM sites after deployment. Specifically, the Dallas U.S.-75 corridor can be characterized as playbook-driven, and the San Diego I-15 corridor as response-plan driven with a set of flexible rules for automated control driven by the decision-support system.

Integrated Consortium (Advanced Model)

In this advanced model (see FIGURE I.5), corridor management roles and practices are well defined and more formal corridor-specific organizational structures are required to improve efficiency and accountability. A new corridor-level organization is formed to carry out these roles and practices, staffed by individuals drawn from stakeholder organizations.

This is the first advanced model and represents a level of coordinated action and formalized organizational form at a tier above both the three early deployment frameworks and the intermediate framework discussed so far. Again, the key difference in this advanced

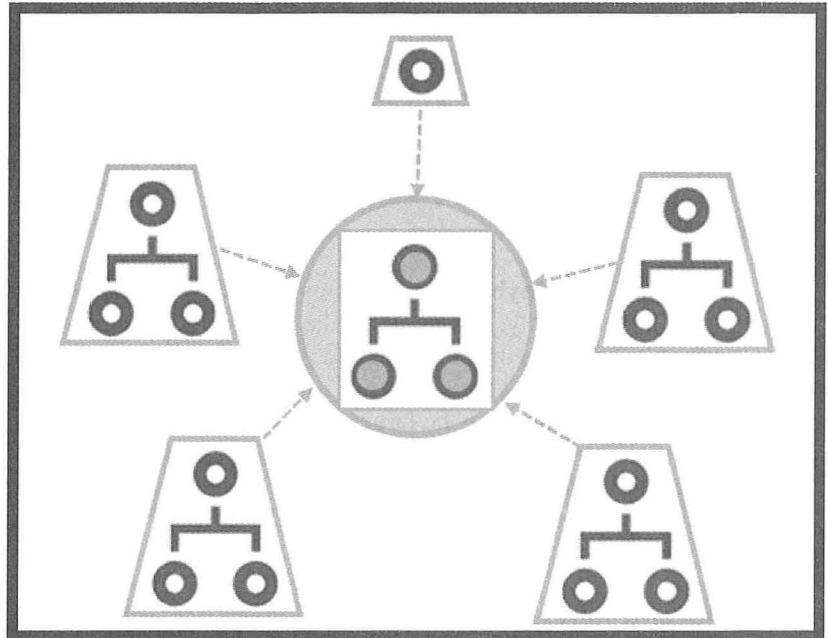


FIGURE I.5. Integrated consortium (advanced model).

model is a more mature set of institutional capital. Specifically, advancing to the advanced framework requires more detailed institutional arrangements that create a new organizational entity, the ICM consortium. The consortium, in turn, is staffed and is operated by members of stakeholder organizations to carry out corridor-specific activity as a full-time or nearly full-time activity exclusive of positions in the individual “home” organization.

In the diagram shown above, the *Integrated Consortium* model can be characterized as a collection of stakeholder organizations (shown at the exterior points of the diagram) sending individuals and staff from their organizations to take roles in the new corridor-specific roles created by the consortium (represented as the element in the center of the diagram). This action provides yet another opportunity to deepen the level of coordinated action and technical integration among ICM stakeholders. Note that the focus of this diagram is at the institutional level—the playbook is no longer the focus. A comprehensive playbook is a given in this advanced framework—and the focus has turned to creating a new organizational model that (in large part) reflects a desire to enhance and execute the playbook as its sole responsibility.

Note that there are no current examples of the *Integrated Consortium* framework currently deployed for the purposes of ICM. The following analysis of strengths, weaknesses, and best applications are based on the experiences outside of ICM. These advanced models may be of interest for consideration by ICM stakeholders but cannot be described as proven ICM organizational models.

Strengths:

- **Corridor-Focused Operational Roles.** Creates an operational organization with the specific goal of the managing the corridor. Rotation in/out of these positions deepens understanding among

stakeholders and reinforces the corridor world view rather than the “coordination of silos” seen in earlier forms.

- **Dedicated Financial Arrangements.** When the new organizational form is created, it requires a supporting financial arrangement. The independent financial stream helps to stabilize and achieve longer-term corridor goals. Drawn from other non-ICM solutions, this means that the management entity is supported by user fees (e.g., aviation passenger taxes, or toll road revenues)
- **Deep Integration.** Playbook approaches have logical limits (described above). The consortium model allows managers to consider higher levels of operational control, including increased use of automation, to optimize corridor management actions.

Weaknesses:

- **Temporary Positions May be Weak.** Individual agencies may not devolve much real power, so the roles created may speed coordination but may not actually achieve deep integration. One observation is that a move to the *Integrated Consortium* model may be difficult without establishing earned trust in an intermediate organizational form.
- **New Organization to Maintain and Support.** The leap to the Integrated Consortium model will require financial and other forms of support from stakeholders. Some organizations may balk at providing staff—others may be reluctant to provide other resources. The benefits of the consortium may be difficult to quantify.

Best Applied:

- **Intermediate Models Exit Strategy.** The intermediate model may not prove sustainable over the long term for institutional reasons. In these cases, a consortium model may be a useful migration path—rather than dissolution of the ICM deployment.
- **Corridor Financial Flows.** Consortium models have been most successful when independent financial flows can be identified. This may be a significant barrier in many ICM solutions.

Examples/Insights:

- **Air Traffic Control.** Some elements of the consortium model can be seen in the world of commercial aviation and the management of the National Air Space (NAS). Traffic flow management is organized around hand-offs among coordinating control centers. Where domestic and international borders intersect, there are governance processes put in place to ensure a comprehensive air traffic control capability.
 - For a description of traffic flow management, see <https://www.nbaa.org/ops/airspace/tfm/concepts/>.
 - For a description of domestic/international coordination governance, see https://reason.org/wp-content/uploads/files/air_traffic_control_governance_testimony.pdf

Third-Party Operator (Advanced Model)

In this advanced model (see FIGURE I.6), corridor management roles and practices are well defined and more formal corridor-specific organizational structures are so well-defined that separate organization is hired or formed to carry out these roles and practices.

This is the most advanced model and represents a level of coordinated action and formalized organizational form at a tier above all other frameworks discussed so far. As in the *Integrated Consortium* model, the key difference in this advanced model is a more mature set of institutional capital. Specifically, advancing to the advanced framework

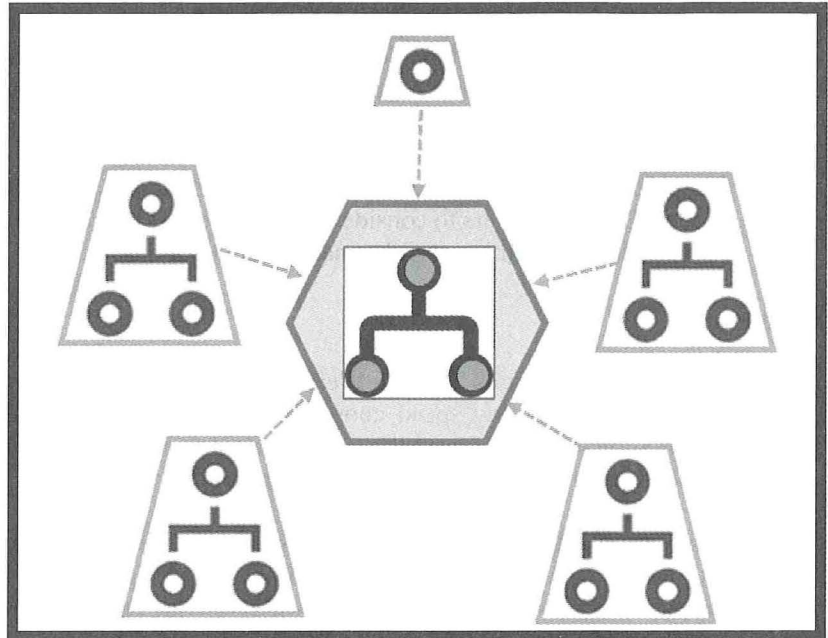


FIGURE I.6. Third-party operator (advanced model).

requires more detailed institutional arrangements that solicit a third-party corridor management entity to enhance and execute defined ICM responsibilities. The third-party entity is free-standing, that is, it is NOT staffed by members of stakeholder organizations. It has defined scope, actions, and methods of financial recovery to conduct corridor-specific activity.

In the diagram shown above, the *Third-Party Operator* model can be characterized as a collection of stakeholder organizations (shown at the exterior points of the diagram) defining the role and responsibility of the third-party ICM operator (represented as the element in the center of the diagram). The third-party ICM operator is shaded green (rather than orange) to emphasize the relationship is focused on a financial relationship and not an institutional trust relationship. Note that the focus of this diagram is at the institutional level—the playbook is no longer the focus. A comprehensive playbook is given in this advanced framework—and the focus has turned over the playbook to a third party who has financial motivation to enhance and execute the playbook.

Note that there are no current examples of the *Third-Party Operator* framework currently deployed for the purposes of ICM. The following analysis of strengths, weaknesses, and best applications is based on the experiences outside of ICM. These advanced models may be of interest for consideration by ICM stakeholders but cannot be described as proven ICM organizational models.

Strengths:

- **Profit-Performance Relationships.** Arrangements put in place are likely to make the third-party operator motivated to improve corridor performance. This may help better align investment and performance in ways not possible with other organizational models. Further, these agreements often

include new capital expenditures from the third party that can be recouped over time through improved corridor performance.

- **Third-Party Operator May Innovate.** The desire to increase profits may bring innovation and new strategies into the corridor that stakeholders had not considered previously—innovations that may be highly effective.

Weaknesses:

- **Lack of Day-to-Day Stakeholder Control.** The playbook needs to be well trusted by the stakeholders as they are likely giving away some aspects of their ability to control their own systems.
- **Fundamentals May Change.** It may not be possible to modify these arrangements significantly after they have been put in place. This can be problematic for financial reasons, and the third-party operator model may not be viable over time. For an example drawn from privatizing toll road operations, see:
 - <https://www.forbes.com/sites/realspin/2014/10/03/the-indiana-toll-road-how-did-a-good-deal-go-bad/>

Best Applied:

- **Stable Corridors and Short Windows.** In an advanced state where corridor conditions and performance are extremely well known, it may be cost effective to consider a third-party operator. However, long operational periods (e.g., 75 years in the toll road example above) expose all parties to significant risk. Stable, well-understood corridors and much shorter operational periods (e.g., 5 or 10 years) may be considered. The downside for the third-party operator for shorter periods is more limited ability to recoup start-up costs and capital investment.

Examples/Insights:

- **Public-Private Partnerships.** FHWA maintains a useful website with guidance on creating and managing a wide range of third-party partnerships: <https://www.fhwa.dot.gov/ipd/p3/>

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

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